Agenda Item 11b
Attachment 1

First Draft Delta Science Plan

One Delta, One Science

June, 18, 2013

FIRST DRAFT DELTA SCIENCE PLAN

This is the first draft of three versions of the Delta Science Plan, which will be presented to the Delta Stewardship Council (Council) in the following order:

June 2013: First Draft Delta Science Plan

August 2013: Second Draft Delta Science Plan

September 2013: Final Delta Science Plan

At each stage of the development of the Delta Science Plan, the Delta Lead Scientist will publicly present the latest draft to the Council for the purpose of receiving information and comments from the Council and the public. All Council meetings are public and simulcast on the Council website at www.deltacouncil.ca.gov.

SUBMITTING PUBLIC COMMENT

Public comments are welcome during the entire Delta Science Plan development process. The Delta Science Program encourages written public comments to be submitted to science@deltacouncil.ca.gov. Please organize written comments by chapter title, heading, appendix, page number, line number and box/figure number.

For public comment on the First Draft Delta Science Plan to be considered for incorporation in the Second Draft Delta Science Plan, comments must be received no later than Thursday, July 18, 2013.

Public comments that address the following are particularly helpful:

1. Major elements to add (i.e., processes and efforts to build on that are not mentioned in the current draft, examples of how to build the community of science and potential science-communication tools)
2. Major elements to delete (e.g., listed actions that are duplicative of existing efforts)
3. Resources and funding recommendations and strategies for implementing the Draft Delta Science Plan
4. Organizational structures identified in the draft (i.e., the Policy-Science Team or the Delta Science Synthesis Team)

THE FOLLOWING POINTS ARE RELEVANT TO THIS PRELIMINARY DRAFT DELTA SCIENCE PLAN

List of Contents is not in final format and there are notations of items throughout the text that need to be completed or otherwise noted.

Glossary of terms is under development and will be inserted as it is completed.

Technical editing for all information in the Draft Delta Science Plan versions, including grammatical and style changes, will be ongoing.

All figures and tables are preliminary. New and updated figures will be inserted as they are completed.

Citations and references are under development and will be inserted as they are completed.

Audiences and Uses of the Plan

Achieving the vision of *One Delta, One Science* requires a new culture of cooperation and stewardship among policy makers, scientists, managers, stakeholders, and the public. To build this community, the following audiences and uses of this plan include:

Audience	**Use the Delta Science Plan to:**
Delta Independent Science Board	♦ Provide oversight of scientific research, monitoring and assessment of programs that support adaptive management of the Delta through periodic reviews of scientific research, monitoring and assessment of programs at least once every four years (Water Code §85280(3)) ♦ Inform recommendations for strategic science planning and activities
Delta Science Program	♦ Guide implementation of its strategic objectives ♦ Guide development and updates to a Science Action Agenda (Action Agenda) ♦ Coordinate and facilitate teams to implement the Delta Science Plan actions and the Action Agenda
Delta Stewardship Council	♦ Inform coordination, advice, and consistency determinations and provide oversight of Delta activities to achieve the coequal goals ♦ Understand necessary science actions that can inform changes to the Delta Plan
Delta managers and resource agencies that have science programs	♦ Guide and articulate the collaboration among programs necessary to implement the Delta Science Plan ♦ Propose adjustments to programs for undertaking activities and contributing to achievement of the Delta Science Plan (including the development and implementation of the Action Agenda)
Delta science community	♦ Foster and enhance networking and collaborative synthesis ♦ Understand and provide input on priority science needs ♦ Provide the context for, implementation approach and elements of the Delta Science Plan ♦ Enhance connections with Delta policy and management communities
Delta managers	♦ Recognize and provide input on priority science needs ♦ Identify the context for, implementation approach and elements of the Delta Science Plan ♦ Enhance connections with the Delta science community
Delta policy makers	♦ Acknowledge and provide input on Delta science needs ♦ Provide the context for, implementation approach and elements of the Delta Science Plan ♦ Enhance connections with the Delta science community
Delta water and environmental stakeholders	♦ Identify priority Delta science needs ♦ Provide the context for, implementation approach and elements of the Delta Science Plan and avenues for engaging with the Delta science community ♦ Enhance connections among Delta policy, management and science communities
Public	♦ Understand the role of science in Delta management as well as the context of the Delta Science Plan and its outcomes

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List of Contents

Executive Summary

Why a Delta Science Plan?

In 2009 legislation was passed that established a new oversight and coordination entity in the Delta. It also tasked this entity with development of a management plan and included certain requirements for that plan. Implementation of the Delta Reform Act and the Delta Stewardship Council's Delta Plan requires science support to achieve the coequal goals of water supply reliability and protecting, restoring and enhancing the Delta ecosystem. The Delta Plan is a long-term management plan that integrates existing State and federal laws and policies and ongoing programs and is informed by the best available science to chart a course to further the coequal goals. While the Delta Plan is a management plan, it recognizes the important role of science to inform implementation actions and includes recommendations and requirements for the expanded use of best available science and adaptive management. On the need for improved coordination of science to achieve goals in the Delta, the Delta plan is clear: "Currently, science efforts related to the Delta are performed by multiple entities with multiple agendas and without an overarching plan for coordinating data management and information sharing among entities" (National Research Council 2012).

In its review of the sustainability of water and environmental management in the California Bay-Delta, the National Research Council found that, "only a synthetic, integrated, analytical approach to understanding the effects of suites of environmental factors (stressors) on the ecosystem and its components is likely to provide important insights that can lead to enhancement of the Delta and its species" (National Research Council 2012). In response to this finding, the Delta Stewardship Council in its Delta Plan recommends that a Delta Science Plan be developed to organize and integrate ongoing science and shared learning in the Delta. The Delta Plan further recommends that the Delta Science Plan address, among other items, effective governance for science in the Delta, strategies for addressing uncertainty and conflicting scientific information, the prioritization of research, near-term science needs and financial needs to support science. It is therefore integral to the success of the Delta Plan and achievement of the coequal goals.

A Vision for Delta Science

This plan lays the foundation for achieving the vision for Delta Science as '*One Delta, One Science'* – an open Delta science community that works together to build a shared body of scientific knowledge. Transitioning from a paradigm of programmatic silos, this open science community would have the capacity to adapt and inform future water and environmental decisions across multiple organizations and programs. It does not mean that the sovereignty of agencies is compromised, regulatory responsibilities are diminished or bottom-up mechanisms for shaping the science community are lost. In fact, it is an essential function of the Delta Science Program to augment and build on already existing efforts and improve the existing science infrastructure where synergies within the science community can be achieved.

Numerous programs address the Delta's large scale, persistent, and difficult policy and management issues ("*grand challenges*"). The Delta Science Plan establishes and sustains a single common body of scientific knowledge on which to base the management and policy decisions to meet these challenges.

The body of scientific knowledge will be based on innovation, trust and sound scientific principles. Differences in ideas and concepts will be embraced and explored through collaborative efforts with a common goal of accelerating understanding to inform the challenging management decisions that must be made.

The Delta Science Plan covers the geographic extent of the Sacramento-San Joaquin Delta (as defined in Section 12220 of the Public Resources Code) and Suisun Marsh (as defined in Section 29101 of the Public Resources Code) and may also address larger-scale processes, functions, and stressors outside its primary geographic focus area that influence conditions within the Delta.

What is the Delta Science Plan?

The Delta Science Plan is the first element of a three-part planning, implementation and reporting strategy. The overall Delta Science Strategy includes three elements:

1. *The Delta Science Plan* sets a shared vision for Delta science and a living framework for guiding, organizing and integrating science in the Delta. It establishes the major elements, organizational structures, and key actions for improving the efficiency, utility and application of Delta science across many agencies and institutions.
2. *The Science Action Agenda (Action Agenda)* prioritizes near-term actions and research to achieve the objectives of the Delta Science Plan. The Action Agenda identifies priorities for research, monitoring, data management, modeling, synthesis, communication, and building science capacity. Under the leadership of the Delta Science Program, the Action Agenda will be developed collaboratively with federal and State agencies, local government, science programs, academic institutions, stakeholders and the Science Synthesis Team (described in Action 2.2).
3. *The State of Bay-Delta Science (SBDS)* is a synthesized summary of the current knowledge from all sources of current scientific understanding. It is written every four years by relevant science experts with guidance from the Science Synthesis Team (described in Action 2.2).

What Does the Delta Science Plan Do?

The Delta Science Plan – the first of the three elements of the science strategy – creates a framework for making scientific information relevant and available to decision makers. It addresses several key needs: synthesis of research and data into useful scientific information, improved communication between scientists and policy makers, guidance for the use of science in adaptive management, and the "infrastructure" needed to support the science enterprise.

Provides Ongoing Science Synthesis

In its most basic sense, "synthesis" means the process of combining objects or ideas into a complex whole (Collins English Dictionary). As used here, it means drawing together the available scientific information (usually scientific papers, reports, and best professional judgment) and building higher-level understanding to answer a key science or management question. The Delta Science Plan will establish a Science Synthesis Team to integrate and synthesize relevant research and current knowledge to inform ecosystem restoration and water management decisions. This single, overarching team is responsible for identifying research priorities, making recommendations for focused work teams to develop specific synthesis products in a defined time period, guiding development of the *SBDS*, and representing the *One Delta, One Science*-Community on the Policy-Science Team.

Improves Policy-Science Communication to Achieve Results

The Delta Science Plan creates a Policy-Science Team that brings together agency leaders and leaders of the scientific community to discuss immediate and long-term issues. These science leaders include lead scientists (e.g., the Interagency Ecological Program Lead Scientist) and representatives from the newly established Science Synthesis Team. The Policy-Science Team will transform the way that scientists and decision makers interact. Together they will identify “grand challenges”, analyze policy alternatives and advise adaptive management of policies and programs.

Coordinates and Provides Science Support for Successful Adaptive Management

The Delta Reform Act and the Delta Plan make adaptive management a requirement for water management and ecosystem restoration. Adaptive management methods will be applied from the project-scale to the system-wide reach of the Delta Plan. Adaptive management is not easy and should be tailored to suit a specific program or project. The Delta Science Plan calls for creation of an Adaptive Management Unit within the Delta Science Program. This unit will include Adaptive Management Liaisons who will interact with their counterparts in the implementing agencies and will assist with development of adaptive management plans and application of guidelines using adaptive management principles for ecosystem restoration actions (*Restoration Framework)* and water management actions (*Water Management Framework)*.

Builds the Infrastructure to Promote Cutting-Edge Science

The cutting-edge science envisioned in the Delta Science Plan cannot be achieved without meeting the basic needs of science programs and scientists, including the ability to adapt to changing technologies and improved knowledge. The Delta Science Program will work closely with other programs to further develop and integrate the following infrastructure components:

- Scientific Capacity
- Research Priorities
- Monitoring and Associated Research
- Data Management and Accessibility
- Shared Modeling
- Synthesis for System-wide Perspectives
- Independent Scientific Peer Review and Advice
- Science Communication

The Future of Delta Science

By taking actions aimed at achieving efficient development of policy and management-relevant science, the Delta Science Plan provides a roadmap for meaningful investments in science to achieve the vision of an ecosystem capable of supporting multiple goals (including sustainability of endangered species, economic development, water supply reliability, recreation and cultural resources). The Delta Science Program, consistent with its mission to provide the best possible, unbiased scientific information to inform water and environmental decision making in the Delta, will play a leadership role in implementing the Delta Science Plan. The Delta Science Program will also become a champion and facilitator for expanding the capacity to implement the actions called for in the Delta Science Plan and to overcome the barriers agency scientists encounter in accessing even the most basic tools required by scientists to inform the multi-billion dollar effort to achieve the coequal goals. The Delta Science Program will work with many partners to become the “go to” source of Delta scientific information and will draw on expertise and resources from across California and the nation. The Delta Science Plan includes an initial assessment of the funding and resources required to meet current and future science needs of Delta water and environmental policy decisions.

1. INTRODUCTION

"Through our joint federal-state partnership, and with science as our guide, we are taking a comprehensive approach to tackling California's water problems…"[1]

Around the world, high expectations exist for science to enlighten and steer natural resources management issues in a direction of sustaining critical ecosystem services, functions, and processes. Implementation of the Delta Reform Act and the Delta Stewardship Council's Delta Plan depend on science support (Water Code §85020(h)) to achieve the coequal goals of a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem (Water Code §85054). Significant scientific investments have been and continue to be made to understand the Delta[2] system to inform water management and environmental decisions. However, despite a rich history of scientific study and more than 40 years of aquatic monitoring, insufficient integration, coordination, cooperation and communication weaken efficient development and effective use of best available science to inform decision making. A new path forward is needed to achieve the vision of *One Delta, One Science* (Box 1-1).

BOX 1-1 VISION

The Delta Science Plan aims to achieve the vision of '*One Delta, One Science*' – an open Delta science community that works collaboratively to build a shared state of scientific knowledge with the capacity to adapt and inform future water and environmental decisions.

A Delta Science Strategy

A Delta Science Strategy is essential for achieving the vision of *One Delta, One Science* and for providing the science needed to support achievement of the coequal goals of the Delta Reform Act. This Delta Science Plan is one of three elements of a comprehensive Delta Science Strategy: 1) The Delta Science Plan, 2) The Science Action Agenda (Action Agenda), and 3) The *State of Bay-Delta Science* (*SBDS*) (Figure 1-1).

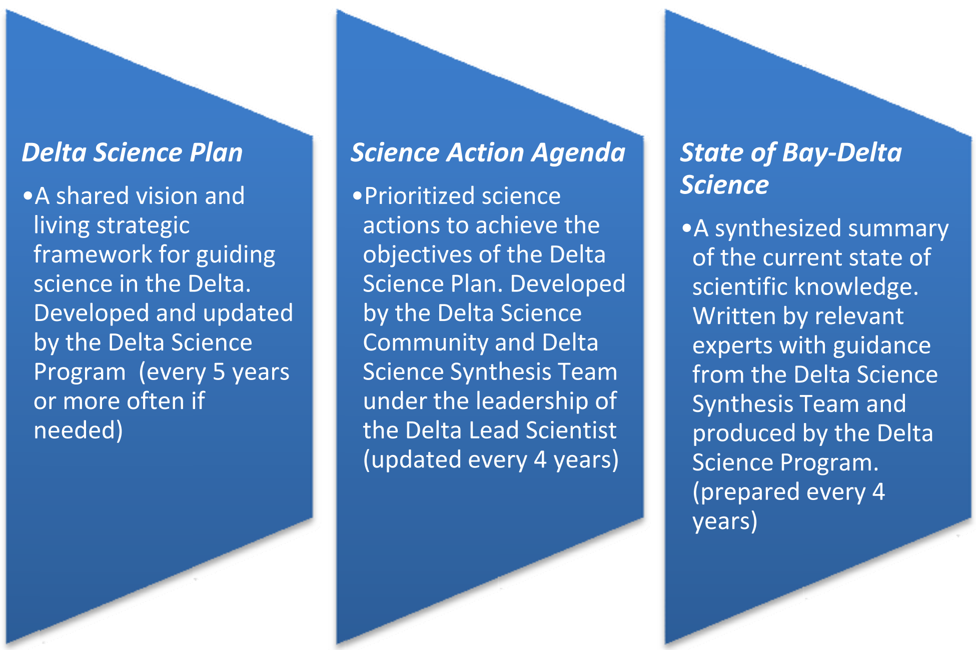

Figure 1-1. The three elements of the Delta Science Strategy. All elements will be reviewed by the Delta Independent Science Board.

[1] From July 25, 2012 Governor Brown and Obama Administration joint announcement on the proposed path forward for the Bay Delta Conservation Plan and California's water future.
[2] The Sacramento-San Joaquin Delta and Suisun Marsh are referred to throughout this document collectively as "the Delta."

The Delta Science Plan

The Delta Science Plan articulates a vision for Delta science and a broad, durable framework for organizing and integrating Delta science. It creates the institutional capacity to support, enhance and network all science programs that contribute to Delta Science. The Delta Science Plan supports infrastructure for making the highest caliber science available for Delta water and environmental decision making, including adaptive management as required by the Delta Reform Act and the Delta Plan (Box 1-2). The Delta Science Plan covers the geographic extent of the Sacramento-San Joaquin Delta (as defined in Section 12220 of the Public Resources Code) and Suisun Marsh (as defined in Section 29101 of the Public Resources Code) and may also address larger-scale processes, functions, and stressors outside its primary geographic focus area that influence conditions within the Delta.

Implementation of the Delta Science Plan will provide independent, peer-reviewed, objective science products to inform Delta decisions aimed at achieving the coequal goals, but expressly will not pass value judgment on the trade-offs between different decisions. It also recognizes the needs for agencies to meet their regulatory responsibilities.

The Delta Science Plan is developed by the Delta Science Program in close collaboration with federal and State agencies, local government, scientists and stakeholders. It is reviewed by the Delta Independent Science Board, the Delta Stewardship Council, federal and State agencies, local government, members of the Delta science community, and additional invited outside reviewers. It will be a living document that is updated every five years or more often if needed.

The Science Action Agenda (Action Agenda)

The Science Action Agenda (Action Agenda) establishes the prioritized science actions to achieve the objectives of the Delta Science Plan. The Action Agenda identifies the "grand challenges" and priorities for research, monitoring, data management, modeling, synthesis and communication to address these challenges for a four-year period. The Action Agenda will be a shared agenda for science programs in the Delta that are housed in multiple federal, State and local agencies, universities and non-governmental organizations. It will serve as the common agenda for developing science work plans (e.g., the Interagency Ecological Program Work Plan). Activities in the Action Agenda will include multiple directed research activities and open competitive research solicitations. The Action Agenda will also support activities to predict potential outcomes of various management and intervention options, often referred to as "alternative futures." In doing so, the Action Agenda will support coordinated and transparent adaptive management. The SAA will retain flexibility to conduct science around unanticipated specific events such as a flood, earthquake, levee failure, salt-water intrusion into the Delta or major releases of hazardous materials.

The Action Agenda will be developed through an open process by the Delta science community (including federal and State agencies, local government, academics, stakeholders and other interested parties) and the Science Synthesis Team (Action 2.2) under the leadership of the Delta Science Program. The Science Synthesis Team will provide high-level guidance for topics to be addressed in the Action Agenda based on key scientific uncertainties. The Policy-Science Team (Action 2.1) will provide high-level guidance on the prioritization of science actions based on "grand challenges" and decision makers' needs. Science action priorities identified at summits and through collaborative efforts for developing community tools (i.e., data management (Action 4.3.1.) and shared models (Action 4.4.1.) will also be incorporated into Action Agenda topics and prioritization. The Delta Lead Scientist has final responsibility for selecting and articulating the rationale for Action Agenda priorities. The four-year cycle of the Action Agenda will be aligned with the Biennial Bay-Delta Science Conference to maximize opportunities to openly engage the science community, policy makers and managers involved in developing and applying scientific information for decision making. The Action Agenda will be reviewed by the Delta Independent Science Board, consistent with its responsibility to provide oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta.

The State of Bay-Delta Science (SBDS)

The *State of Bay Delta Science (SBDS)* is a synthesized summary of the current knowledge related to the Delta from all sources of scientific understanding. Specifically, the *SBDS* communicates the state of knowledge to address the "grand challenges", including progress made on key research questions. It also guides updates to the Action Agenda.

The *State of Bay Delta Science* will be published every four years. *SBDS* will be written by relevant experts with guidance from the Science Synthesis Team. It is the responsibility of the Delta Science Program to produce the *SBDS*. The four-year cycle of *SBDS* will be aligned with the Biennial Bay-Delta Science Conference (offset from development of the Action Agenda). SBDS will be reviewed by the Delta Independent Science Board.

BOX 1-2 DELTA PLAN RELATIONSHIP

"[The Delta Science Plan] is essential to support the adaptive management of ecosystem restoration and water management decisions in the Delta." - Delta Plan

The following highlights the relationship of the Delta Science Plan to implementation of the 2009 Delta Reform Act and the Delta Stewardship Council's Delta Plan. The Delta Reform Act requires the Delta Plan to be based on and implemented using best available science. Furthermore, the legislation requires the use of science-based, transparent, and formal adaptive management strategies for ongoing ecosystem restoration and water management decisions. The Delta Plan also identifies the need for a comprehensive science plan for the Delta and recommends that the Delta Science Program, working with others, develop a Delta Science Plan that creates an overarching roadmap for organizing and integrating ongoing scientific research, monitoring, analysis, and data management among entities by December 31, 2013. To ensure that best science is used to develop the Delta Science Plan, the Delta Plan recommends that the Delta Independent Science Board review the draft Delta Science Plan.

The Delta Science Plan is linked to assisting in the implementation of these elements of the Delta Reform Act and the Delta Plan:

1. Through the Delta Science Program, develop, coordinate and provide the best possible and transparent scientific information to inform water and environmental decision making in the Delta. (Delta Reform Act 85280 (b)(4))
2. The Delta Plan shall be based on the best available scientific information and the independent science advice provided by the Delta Independent Science Board, and include a science-based, transparent, and formal adaptive management strategy for ongoing ecosystem restoration and water management decisions. (Delta Reform Act 85308 (a) and (f)).
    - 2.1 As relevant to the purpose and nature of the project, all covered actions must document use of best available science (as described in Appendix A) (GP 1). Best available science is developed through a process that meets the criteria of (1) relevance, (2) inclusiveness, (3) objectivity, (4) transparency and openness, (5) timeliness, and (6) peer review (NRC 2004).
3. Implement the Delta Plan using adaptive management principles in a coordinated and collaborative way.
    - 3.1 Periodically update the Delta Plan as an adaptive management plan
    - 3.2 Provide guidance for proponents of covered actions to assist in achieving consistency with the adaptive management elements of GP 1 (Delta Plan) including coordinating design, data storage and analysis.
4. Monitoring progress toward achieving the coequal goals (Ch. 2).
    - 4.1 Monitoring for performance measurement evaluation of the Delta Plan.
    - 4.2 Where appropriate, utilize monitoring, data collection, and analysis of actions sufficient to determine progress toward meeting the quantified targets (Delta Reform Section 85308 (c)).
    - 4.3 Monitoring performance of covered actions, as well as implementation outcomes of water management plans
5. Address Science and Information Needs:
    - 5.1 Refining and developing numerical and simulation models along with enhancing existing Delta conceptual models (G R1).
    - 5.2 New or improved models (Ch. 3, 4, and 6).
    - 5.3 Organize and integrate ongoing scientific research, monitoring, and learning about the Delta as it changes over time (Delta Plan Ch. 2, p.44.1).
    - 5.4 Recommendations on an integrated approach for monitoring that incorporates existing and future monitoring efforts (Delta Plan GR1).
    - 5.5 Where appropriate, recommend integration of scientific and monitoring results into ongoing Delta water management (Delta Reform Act 85308 (e)).
6. Communication and the Delta Plan - "The Council is committed to open communication of current understanding gained through the evaluation of performance measures, monitoring, science, and adaptive management." (Delta Plan Ch. 2)
    - 6.1 Develop an interagency structure for decision-making that fosters communication among scientists, decision makers, and stakeholders.
7. Provide a strategy for leveraging reliable funding to sustain needed science advancements and infrastructure.

The Overarching Problem Addressed by the Delta Science Plan

Of the many science efforts in the Delta, few address more than a single objective or pragmatic question. The Delta Plan summarizes this problem:

> *"Currently, science efforts related to the Delta are performed by multiple entities with multiple agendas and without an overarching plan for coordinating data management and information sharing among entities. Increasingly, resource management decisions are made in the courtroom as conflicting science thwarts decision making and delays action. Multiple frameworks for science in the Delta have been proposed, but a comprehensive science plan that organizes and integrates ongoing scientific research, monitoring, analysis, and data management among entities has yet to be fully formulated."*

Despite the close working relationships of many individual scientists and the collaborative efforts of focused programs such as the Interagency Ecological Program (IEP), it is very difficult to track all activities on a given topic, including data generation, model development and calibration, and new results and insights gained. While coordination of Delta efforts occurs, fragmented approaches to planning, regulation and management threaten effective and efficient management of the Delta ecosystem (Hanak et al. 2013). A structure and process to facilitate sustained integration are distinctly lacking. This makes it very difficult to provide the needed broad knowledge base of scientific information synthesized from multiple sources, a variety of scientific disciplines and geographic areas, and across different time scales and jurisdictional topics. In addition, generally accepted and adequately supported organizational structures and processes do not exist for ongoing scientific synthesis. Not surprisingly, there are only a few examples of broad synthesis efforts in the Delta. These synthesis activities are essential to delivering the best available science needed to support policy and management decisions.

Efforts to Build On:

- Collaborative science planning efforts by the Interagency Ecological Program, Bay Delta Conservation Plan, State Water Resources Control Board, Biological Opinions Remand Process, California Water Plan Update Process and the South Delta Salmonid Research Collaborative
- Multi-agency sponsorship of Delta Science Fellows solicitations
- Recent State Water Resources Control Board workshops
- Research needs identified by BDCP
- Delta Science Program Proposal Solicitation Package process for identifying research priorities
- IEP Management Analysis and Synthesis Team (MAST)Pilot effort

This Delta Science Plan respects the sovereignty of agencies, institutional missions, and legal mandates while providing a shared science plan for Delta programs. Implementation of the Delta Science Plan will enable scientists to be more productive through interagency collaboration, integration and the use of common tools. Where possible, this plan builds on existing organizational structures to provide this coordination, synthesis and communication.

What are the Key Issues the Delta Science Plan Addresses?

Coordination and Integration of Delta Science- Current fragmentation of science institutions hinders efficient development and use of a common and trusted body of science for Delta decision making. These fragmented science institutions do not have the capacity to efficiently address "grand challenges" that will need rigorous science support to address the coequal goals (Box 1-3). This Delta Science Plan addresses "grand challenges" through a shared approach for organizing and integrating ongoing scientific research, monitoring, data management, analysis, synthesis and communication.

Science Synthesis- The lack of a collaborative mechanism for synthesis hinders the timely translation of information into usable knowledge. This plan will establish a Science Synthesis Team (facilitated by the Delta Science Program) tasked with integrating and synthesizing relevant research and current knowledge to inform ecosystem restoration and water management decisions (Action 2.2).

Science-Policy Communication- Communication channels between decision makers and the broad science community (comprising federal and State agencies, universities, non-governmental science programs and consultants) are currently limited. Furthermore, the roles of science (to inform decision making) and the roles of policy and managers (to prioritize and make decisions) are not always clearly understood. Challenges to communicate and develop a shared understanding of needs, opportunities and roles at these interfaces have led to considerable frustration. This plan provides a new path forward for improving communication at these interfaces through establishing a Policy-Science Team, which includes Directors of federal and State agencies, Delta Science Leaders and select members of the Science Synthesis Team (Action 2.1). This team will facilitate shared understanding of policy priorities and scientific information and the direct communication of new understanding into actionable alternatives for management and policy changes.

BOX 1-3 – Grand Challenges for Science and Management

- **Basic science** to understand the dynamic state of the estuary and how the major stressors (altered hydrology, physical alterations of the landscape, invasive species introductions, and pollutants) affect ecosystem restoration outcomes and water supply reliability.
- **Delta change management** that anticipates step-changes in the shape or state of the contemporary Delta from floods, seismic events, toxic spills, or new introductions of invasive species. This grand challenge requires skilled and rapid decision-support for prioritizing and executing responses.
- **Operation of the Delta – from Sierra to the sea** for water supply reliability, flood management, and power benefits, subject to physics, standards, and regulations, by articulating alternative regulatory futures that meet the coequal goals ever better; and to plan to operate the Delta of the future – the one that shows up both by accident and design.
- **Restoration** to purposefully change the Delta ecosystem to support conservation of native species at the system-scale. Restoration at the Delta-scale will take decades, defy biological performance measures, and continually confound and surprise us. Restoration actions (past, present and future) will affect one another, and staging restorations to be ecologically relevant is a must.

Effective Adaptive Management- Past attempts to adaptively manage Delta water operations and habitat restoration have rarely covered the full adaptive management cycle (Plan, Do, Evaluate and Respond). There is a risk of not being able to attain or quantify system-level progress toward achieving the coequal goals if multiple adaptive management efforts are incomplete, nonintegrated, or fail to consider system-wide and local effects. Under the Delta Science Plan, adaptive management implementation will be integrated through a Restoration Framework, a Water Management Framework and Delta Science Program Adaptive Management Liaisons (Ch 3).

Identifying, Maintaining, and Advancing the "State of Delta Knowledge"- The state of knowledge of the Delta system is advancing rapidly and distributed across many institutions, which makes it difficult to assimilate in a timely manner. This plan will facilitate the maintenance and growth of Delta-wide knowledge through the activities of the Science Synthesis Team, Policy Science Team, and the Delta Science Program. The Science Synthesis Team and Policy Science Team will play key roles in establishing Delta-wide approaches for prioritizing research (Ch 4.1), integrating monitoring and associated research (Ch 4.2), and conducting targeted and ongoing synthesis activities (Ch 4.5). The Delta Science Program with others will facilitate Delta-wide approaches to data management and accessibility (Ch 4.3), shared models (Ch 4.4), and independent peer review (Ch 4.6). To more effectively inform policy and management decisions and the public, this plan develops a number of information sharing avenues (Ch 4.7).

2. ORGANIZING SCIENCE TO INFORM POLICY AND MANAGEMENT

"A collaborative effort is needed, where scientists and governance professionals work together as a single team, rather than two separate entities."[3]

Transformation of how policy, science and management communities engage is essential for identifying and addressing complex questions and issues surrounding natural resources management in the Delta. Transformation means adjusting the way we work as policy makers, scientists and resource managers, learning each other's "language," and embracing a team approach. This means working together to articulate problems, set goals and priorities, increase understanding, and share in progress toward achieving the coequal goals. This plan establishes and strengthens forums for decision makers and scientists to work together to evaluate alternative Delta futures through early engagement, continuous dialogue and opportunities to develop innovative approaches for using best available science. Better connections among policy makers, scientists and managers are needed along

Efforts to Build On:

- Town Hall Meeting with policy makers and the science community at the 2012 Bay-Delta Science Conference
- 2012 DSP-coordinated invited Science Expert Panels to synthesize the state of knowledge for State Water Resources Control Board members for the Bay-Delta Plan Phase 1 Update.
- National trends of science networks, for example: Hubbard Brook Research Foundation (HBRF) Science Links Program model of policy-relevant science synthesis and decision-maker engagement (Box 2-3)

[3] National Research Council on Sustainability of Water and Environmental Management in the California Bay-Delta Report (2012), Page 175

with new mechanisms, organizational structures and tools for regular and effective interactions to improve shared understanding and stewardship of the Delta.

Problem

Fragmented science institutions do not have the capacity to efficiently and rigorously address "grand challenges" (Box 1-3) and conduct the broad synthesis activities that achieve the coequal goals. Also, communication channels between decision makers and scientists beyond the bounds of individual organizations are not clearly established. Furthermore, the roles of science (to inform decision making) and the roles of policy and managers (to prioritize and make decisions) are not always clearly understood.

Objectives

- Collaborative processes for ongoing science synthesis to develop shared scientific understanding
- A shared approach for identifying and communicating decision makers' "grand challenges" and the associated priorities for research, monitoring, and evaluation to address these challenges
- Trust and forums for identifying and communicating the key scientific uncertainties that are likely to limit restoration and water management effectiveness and return on investment
- Mechanisms for early engagement of decision makers in setting research and monitoring priorities, continuous dialogue and effective use of best available science to inform decision making

Actions

2.1 Establish a **Policy-Science Team** (PST) to direct science activities toward the decisions of today while researching the anticipated challenges of the future. Directors of federal and State agencies and science leaders will together identify "grand challenges" to inform the development and updates to the Action Agenda and associated science research agendas. This team is also the forum for Directors to explore issues directly with leaders of the scientific community and for scientists to fully understand what science is needed to support decisions and how this information can be best used. The PST will also direct committees as needed to collaboratively analyze policy alternatives and advise adaptive management of policies and programs. The objective of the PST is to ensure there is a high level of trust and understanding between decision makers and the community of scientists on whom they depend. This enhanced communication will assist the delineation between the contribution of science and the essential value judgments that must go into each decision.

The objective of the PST is to ensure there is a high level of trust and understanding between decision makers and the community of scientists on whom they depend. This enhanced communication will assist the delineation between the contribution of science and the essential value judgments that must go into each decision.

Membership will include the Directors of federal and State agencies with water and environmental decision-making responsibilities in the Delta and science leaders appointed by the Delta Lead Scientist. The science members will include a subset of the Science Synthesis Team (Action 2.2) and invited science leaders on the topic under consideration (i.e., the IEP Lead Scientist, BDCP Science Manager, Leading Academic Researchers, and Agency Research Program Directors). The PST will be co-chaired by a rotating Agency Director and the Delta Lead Scientist, and facilitated by the Delta Science Program.

The PST will meet to provide overarching direction and set the “grand challenges” for developing and updating the Action Agenda. The PST also meets to (a) receive early notice of findings in the *SBDS*, (b) address major science issues at the request of a Director or Delta Lead Scientist, (c) provide overarching direction at the start of a 4-year Action Agenda process, (d) plan specific activities, such as Town Hall meetings at the Bay-Delta Science Conference, (e) receive scientific feedback or information. The PST will meet at least once per year.

2.2 Establish a **Science Synthesis Team** (SST) facilitated by the Delta Science Program. This team provides the function recommended by the National Research Council (2012), “a synthetic, integrated, analytical approach to understanding the effects of suites of environmental factors (stressors) on the ecosystem and its components is likely to provide important insights that can lead to enhancement of the Delta and its species.” This team will integrate and synthesize relevant research and current knowledge to inform ecosystem restoration and water management decisions. This will be accomplished through collaborative processes for conducting science. It will enable interdisciplinary scientists from federal, State and local agencies, academia and non-governmental organizations to participate in synthesis activities that result in best available science to inform resource management (including adaptive management approaches) and policy decisions. Members of this team will be selected by the Delta Lead Scientist for their scientific expertise rather than as representatives of agencies, institutions or interest groups. The SST will:

1) Translate the “grand challenges” articulated by the PST into specific research priorities and actionable questions,
2) Recommend topics for focused science synthesis teams efforts that can be developed into specific products in a defined time period and at the appropriate level of synthesis (refer to Ch 4.5),
3) Provide high-level guidance for topics to be addressed in the Action Agenda based on key scientific uncertainties,
4) Provide guidance to relevant science experts writing *SBDS*, and
5) Represent the *One Delta, One Science*-Community on the Policy-Science Team.

The focus of synthesis topics that identify and explain science-based alternatives will be prioritized and selected by the Policy-Science Team. SST products will be communicated upon completion. Products will be compiled into reports. These reports and associated peer-reviewed publications will represent best available science for many subjects and build the knowledge base for Delta science over time. Synthesis methods will be consistent with the Delta Collaborative Analysis and Synthesis approach (Ch 4.5).

2.3 Create **Focused Science Synthesis Teams**. These teams will be recommended by the SST and appointed by the Delta Lead Scientist and facilitated by the Delta Science Program, as needed. Focused Science Synthesis Teams will synthesize the state of knowledge on specific topics, e.g., the pelagic organism decline or the role of ammonium/ammonia in the estuary. Focused science synthesis topics will include recommendations from the Science Synthesis Team and topics identified by the Delta Lead Scientist or Delta Independent Science Board. The Delta Science Program in consultation with others will develop the scope of work and the charge for the focused science synthesis teams with the final approval by the Delta Lead Scientist. The Delta Science Program will aid in the communication of these teams' products. Synthesis methods will be consistent with the Delta Collaborative Analysis and Synthesis approach (Ch 4.5).

2.4 Identify opportunities and mechanisms for reorganizing science institutions to address anticipated "grand challenges" for which science will be called upon to support decisions (Box 1-3).

2.5 Hold legislative briefings. To build relationships and exchange between the legislature and the Delta science community, the Delta Science Program will facilitate:

1. Select scientists from the Policy-Science Team will support communication of science issues to the legislature
2. Members of the legislature, Policy-Science Team and top scientists will meet twice per year for presentations on new findings and their implications to address "grand challenges"

2.6 Link interagency and coordinated science efforts and work plans. Together with other science-supporting entities (i.e., IEP, BDCP, Ecosystem Restoration Program, California Water Quality Monitoring Council and State and Federal Contractors Water Agency), implement the Action Agenda (Ch 1).

2.7 Create and sustain a web-based tracking system that captures information about research projects, monitoring, modeling and other aspects of Delta science.

Expected Outcomes

- Ongoing and collaborative prioritization of science actions (Action Agenda) and assessments of new knowledge (*SBDS*) that reflects the dynamic nature of the Delta-system, advances in technologies and the rapidly growing knowledge base
- Common use and clear direction for using best available science in decision making (i.e., common use of a best available science protocol or checklist)
- Shared understanding of best available science and critical uncertainties among scientists and decision makers
- Synthesized and current applicable science is provided to decision makers to inform policy development and management decisions through joint exploration of "what if" questions and evaluation of alternative futures
- Improved communication at the policy-science-management interfaces
- A Science Synthesis Team that can be convened at short notice to discuss critical issues with decision makers

- Science work plans (including targeted studies and synthesis activities) based on key scientific uncertainties relevant to decision makers' needs
- Integrated science efforts and work plans among agencies and programs
- Coordination, tracking and leadership provided by the Delta Science Program

Box 2-3 Hubbard Brook Research Foundation (HBRF) Science Links Program

Creating effective Policy-Science-Management interfaces in the Delta will build on positive examples from elsewhere. One of these examples is the Hubbard Brook Research Foundation (HBRF) Science Links Program. The HBRF Science Links Program fosters policy-relevant synthesis of science, the distillation of results and communication outreach (Driscoll et al. 2011). Through an inclusive and open process, the HBRF Science Links Program successfully developed and communicated policy-relevant science synthesis to inform policy decisions, which resulted in updates to legislative bills (Clean Power Act and Clear Skies Act), administrative rules (Nitrogen Budget Program and Clean Air Interstate Rule) (Driscoll et al. 2011). The Science Links Program achieved this through a process of continuous engagement between policy makers, scientists and stakeholders during science synthesis efforts. Teams of policy makers and scientists were assembled to frame policy-relevant synthesis questions. Overview Briefings were held early on to engage a range of stakeholders from nongovernment organizations, trade organizations, and state and federal agencies – building an informal network to consider and apply analyses. Projects took 3-4 years to complete, resulting in synthesis articles authored by members of the science teams and the Science Links project manager. Informational briefings with stakeholders were held for previewing findings while results underwent peer review. Soon after publication, the Science Links Program presented synthesis of current knowledge to public-sector entities with direct oversight for the synthesis issues in an effort to connect best available science to specific policy actions. By 2011, the Science Links Program had held over 100 policy briefings, and its reports directly informed the policy decisions described above. The reports *Acid Rain Revisited* (Driscoll et al. 2001b) and *Nitrogen Pollution* (Driscoll et al. 2003b) supported the need for greater emissions controls, which were implemented in short order, following their publication.

3. ADAPTIVE MANAGEMENT FOR A COMPLEX SYSTEM

"'Adaptive Management' means a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvement in management planning and implementation of a project to achieve specified objectives."[4]

Several Delta planning and policy efforts have now adopted adaptive management as the path forward for managing complex natural resources programs and projects (Box 3-1). Adaptive management is a strategy for making management decisions under uncertain conditions rather than delaying action until more information is available or adopting a prescriptive rigid approach. Adaptive management has been successfully applied at the individual project level, but rarely at the programmatic and landscape scales. To successfully implement adaptive management at the large scale of the Delta, new strategies are needed to better define and describe the roles and responsibilities of policy, science and management. These new strategies need to allow for decisions that involve different time periods, different portions of the Delta and different water management and ecological issues. Adaptive management is a continuous and iterative process, in which new insights and solutions aim to improve understanding of

[4] Delta Reform Act § 85052

the problem, which in turn leads to the next generation of actions based on lessons learned from previous actions.

Delta Science Plan actions are based on the three-phase, nine-step adaptive management process outlined in the Delta Plan (Figure 3.1). This chapter explains how the structures and processes identified in other Delta Science Plan chapters are applied to adaptive management. It focuses on how to best move toward continual knowledge application in water management and habitat restoration, combined with continual knowledge acquisition as actions are implemented.

Box 3-1 Example Delta Plans Utilizing Adaptive Management

- Delta Plan
- Draft Bay Delta Conservation Plan
- Bay-Delta Water Quality Control Plan
- Water Quality Control Plans for the Bay Area and Central Valley Regional Boards
- Central Valley Project/State Water Project (CVP/SWP) Biological Opinions
  - Real-time Water Operations
  - Fish Restoration Program Agreement
  - Yolo Bypass Salmonid Restoration and Fish Passage Implementation Plan
- Ecosystem Restoration Program Conservation Strategy
- Suisun Marsh Plan
- California Water Plan
- Integrated Regional Water Management Plans

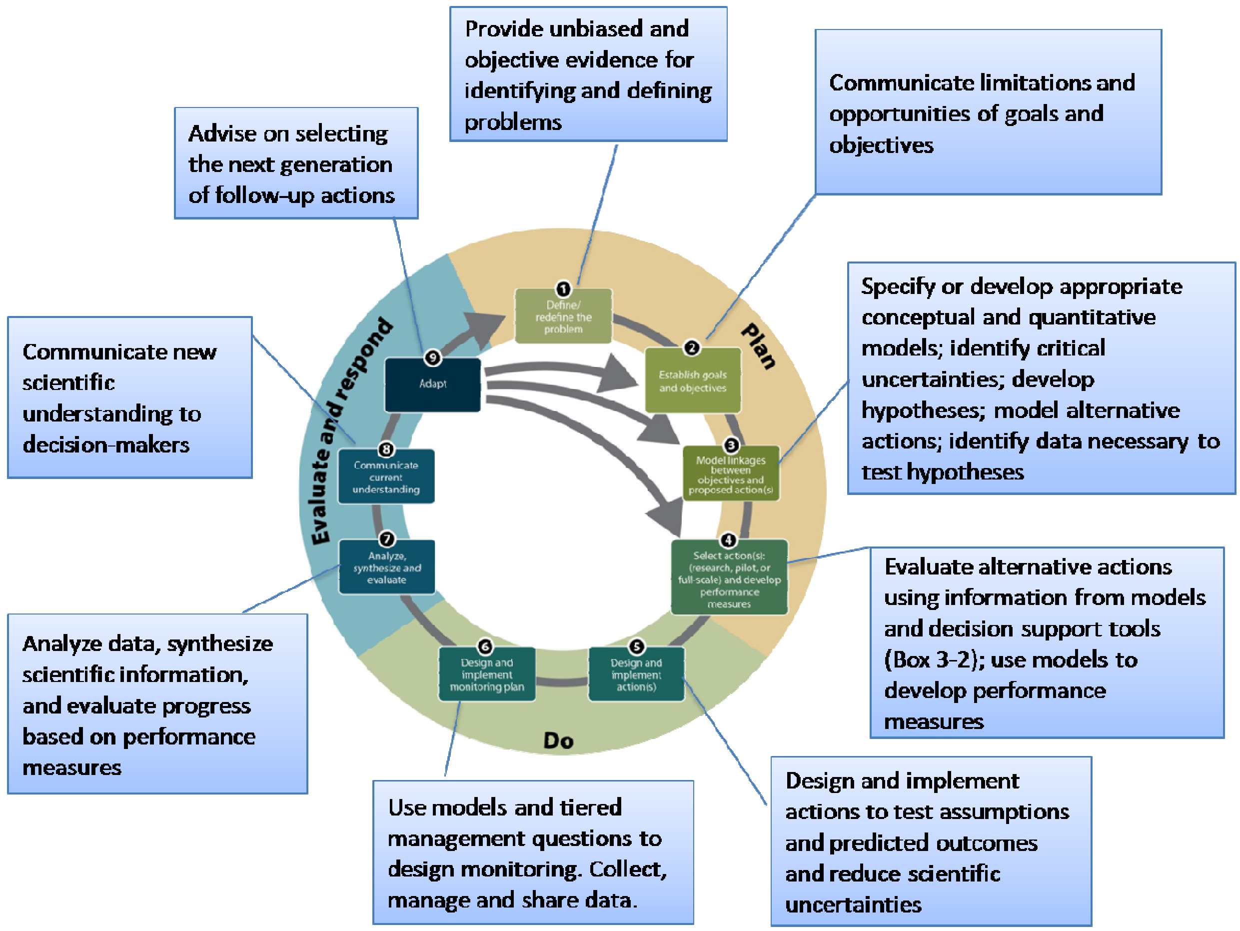

Figure 3-1. Delta Plan Adaptive Management Framework with the role of science called out in boxes for each step.

Box 3-2 Decision Support Tools for Adaptive Management

Clearly articulated conceptual models that specify key state variables, describe their dynamic interrelationships, and project consequences of alternative management actions are a key component of adaptive management (Walters 1986). Models are extremely valuable for formalizing the link between management objectives and proposed actions to clarify how and why each action is expected to contribute to those objectives. They also provide a venue to identify areas of uncertainty, assess the likelihood of success, identify potential restoration or water management actions, develop expectations and performance measures, and define monitoring needs.

The Delta Regional Ecosystem Restoration Implementation Plan conceptual models were developed for the purpose of showing the characteristics and dynamics of the Delta ecosystem, qualitatively predicting ecosystem and species response to specific changes in ecosystem attributes, and providing the science-based information needed to determine whether a restoration action would result in (or contribute to) a desired management outcome. These models are valuable tools themselves, but were designed to provide information for use in structured assessments of proposed restoration actions through the DRERIP Action Evaluation Procedure and Decision Support Tool. The Delta Science Program will expand the utility of this tool to water management decisions and make it an integral component of the Water Management Framework.

Problem

Past attempts to adaptively manage Delta water operations and habitat restoration have rarely covered the full adaptive management cycle (Plan, Do, Evaluate and Respond).. System-level progress toward achieving the coequal goals might not be possible if multiple adaptive management efforts are incomplete, nonintegrated, or fail to consider system-wide and local effects.

Objective

Water management and ecosystem restoration are consistent with the Delta Plan adaptive management approach and with user guidance in Appendix 3 to efficiently improve system-wide understanding in the face of uncertainty. Attributes include:

- Management and policy decision-making processes take advantage of cutting-edge research and monitoring results that are communicated clearly. New understanding is incorporated into the next generation of management actions responsive to scientific findings. Managers and policy makers apply new knowledge acquired through innovative visualization and communication tools on a continuous basis. Models, valid scientific designs responsive to management questions, common metrics, and results shared and accepted by the Delta scientific community are communicated and "translated" to the management and policy-making community for newly informed action.
- Significant plans and important products undergo periodic independent peer review.
- Elements specific to habitat restoration and water management are shown in Box 3-3.

Actions

3.1 The Delta Science Program, in collaboration with key partners, will co-host a summit on adaptive management with national and international experts and local proponents from federal, State and local agencies, non-governmental organizations, private organizations and academia. The summit participants will explore the development and use of guidelines (such as Restoration and Water Management Frameworks) and venues (such as the Delta Restoration Network) to support collaborative science-based adaptive management in the Delta.

3.2 Develop a *Restoration Framework* to guide adaptive management of Delta ecosystem restoration actions and a *Water Management Framework* to guide adaptive management of Delta water management actions. Framework attributes include:

i. Integration of adaptive management activities to improve nesting of adaptive management projects into landscape-scale efforts, shared learning and efficient use of resources.
ii. Institutional arrangements to sustain scientific assessment and support rapid, nimble, and authoritative management decisions at appropriate time intervals (water operations decisions generally occur at more frequent intervals than habitat restoration decisions).
iii. Use of conceptual models including landscape-scale conceptual models for priority restoration areas based on historical ecology and latest science
iv. Emphasis on hypothesis-testing and linkage to companion science programs
v. Use of broadly accepted and transparent quantitative models to analyze alternative futures (short- and long-term) and address "what if" questions
vi. Expert evaluation and peer review of project design
vii. Monitoring, data management and evaluation consistent with system-wide efforts and Delta Science Plan recommendations

Box 3-3 Elements of Integrated Adaptive Management

Habitat Restoration

- Shared landscape-scale conceptual models that incorporate documented landscape functions and processes from historical ecology research (Action 5.4.2)
- Qualitative and quantitative modeling and expert opinion assessment ("DRERIP evaluation") of possible restoration design outcomes (Boxes 3-2 and 3-3)
- Means to compare restoration outcomes to quantifiable goals and performance measures to adjust future management steps if needed

Water Management

- Coordinate real-time water operations of the Central Valley Project/State Water Project with real-time physical and biological data
- Support facilities operations with real-time modeling
- Use an interdisciplinary approach to evaluate "what if" scenarios for optimizing water supply, species protection and other beneficial uses (e.g., hydropower, agricultural and municipal uses, recreation and harvest fisheries).

Box 3-3 Ecosystem Restoration At Prospect Island And Yolo Ranch - DRERIP Evaluation.

Prospect Island and Yolo Ranch are individual restoration initiatives in the Delta identified to satisfy biological opinion requirements for delta smelt and salmon habitat. Historically, the process of planning and implementing habitat restoration in the Delta and Suisun Marsh has been long and unsatisfactory. Obtaining clarity on project objectives, understanding landscape potential, managing property, acquiring permits, and making scientific observations are among the challenges the agencies face.

Anticipating future restorations, the Ecosystem Restoration Program commissioned several conceptual models about Delta ecosystem processes, habitats, stressors and life history of key fishes. The purpose of the conceptual models is to support restoration project designs by evaluating them against the best available scientific understanding on a variety of issues. The evaluation process engages the conceptual model authors and other recognized experts to consider the effects of restoration design alternatives on such issues as mercury methylation potential, aquatic vegetation recruitment and establishment, primary productivity, creation of salmonid and delta smelt habitat, predation, and changes in regional hydrodynamics and generate an emerging consensus on the range of management actions that might achieve desired outcomes, while keeping in mind both risks to investments and those associated with unintended consequences. The up-to-date scientific information was then vetted with managers that considered it in formulating their implementation design.

Given the scale of planned ecosystem restoration, the process for evaluating projects must be much more adept and swift than it has been in the past. The Prospect Island and Yolo Ranch evaluations have been instructive both because design improvements emerged from the discussion, and the dynamics of the group deliberations illustrate how complex restoration actions can be effectively carried out. While the design evaluations were somewhat different, several important lessons were learned. First, the evaluations demonstrated the value of historical ecological assessment. The landscape position of the projects and broader regional physical and biological context provide essential clues about landscape ecological potential. Second, significant hydrodynamics and transport modeling was completed prior to the evaluation about such metrics as current structure, water exposure time, and regional tidal range effects. Modelers were in the room and were able to demonstrate concepts in real time that elevated the group understanding of key processes. Third, landscape changes will initiate a complex and non-linear cascade of processes and outcome trajectories that are difficult to predict with certainty. There was a deep recognition that the projects will affect, and be affected by, the regional ecosystem, especially as it changes in the future from climate change and additional restoration. Finally, many participants agreed that the evaluation process would be improved if a regional landscape conceptual model had been incorporated from the beginning with advance insights about the sensitivity of tidal energy, currents, turbidity, and fish-habitat behavior (to name a few) to landscape changes. The designs of both projects were changed based on this scientific evaluation.

viii. Focused synthesis and communication of the state of knowledge needed to inform adaptive management decisions

ix. Scientific oversight by the Delta Independent Science Board

3.3 Utilize the Restoration and Water Management Frameworks through new or established regional and system-wide team efforts such as the Delta Conservancy's Delta Restoration Network.

3.4 Establish a team of Delta Science Program staff members with expertise in adaptive management. These staff members serve as Adaptive Management Liaisons to their counterparts in agencies and organizations that are planning and implementing adaptive management. Build DSP staff capacity to assist project proponents to develop and implement effective adaptive management programs and projects including Delta Plan covered actions (Box 3-4). This includes assistance in considering and using established guidelines for adaptive management (Appendix 3) in the planning stages of an adaptive management program.

3.5 Explore the efficacy of voluntary certification of adaptive management plans, programs and projects.

3.6 The Delta Science Program will expand the utility of the DRERIP Action Evaluation Procedure and Decision Support Tool to water management decisions and make it an integral component of the Water Management Framework.

3.7 Develop a shared tracking system for all adaptive management programs and a system-wide monitoring and evaluation program to assess the cumulative effects of individual adaptive management programs. Information can be used to update large-scale adaptive management plans including the Delta Plan, BDCP and Bay-Delta Plan.

Box 3-4 Delta Science Program Adaptive Management Liaisons

The Delta Reform Act and Delta Plan require the use of an adaptive management framework to improve the planning, implementation and evaluation of projects. The Delta Science Program will make available adaptive management liaisons for early consultation on adaptive management for Delta Plan proposed covered actions. Early consultation for covered actions will assist project proponents to obtain consistency determinations and increase the likelihood that the best alternative for implementation is chosen to advance program, plan, and system-wide goals and objectives.

Proponents of actions that do not require consistency determinations under the Delta Plan may also benefit from the advice of Delta Science Program staff prior to the implementation phase of a project or plan, especially those that have the potential to: (1) substantially advance the co-equal goals; (2) are likely to add to the knowledge base and reduce uncertainties related to achieving performance measures in the Delta Plan; and (3) are likely to reduce other significant barriers to large-scale restoration or water management improvements, such as regulatory constraints.

There are several advantages of early involvement by Delta Science Program staff in non-covered actions and those that are outside of the Council's geographic jurisdiction but could have significant direct or indirect benefits to Delta ecosystem functions or decrease reliance on water exports from the Delta. They may include:

- ✓ increased competitiveness in future grant applications for Integrated Regional Water Management projects, the Carbon Cap-and-Trade Auction Investment fund, and other sources
- ✓ savings in staff time for project proponents resulting from information on regional monitoring and other activities, advice on conceptual models and assistance in networking with other programs
- ✓ a greater degree of accountability and transparency via broadly applicable performance measures via a standardized approach to the use of science across agencies and programs

Outcomes

- Resources are used efficiently to achieve faster and more effective implementation of water management and habitat restoration.
- Individual adaptive management programs and plans have greater consistency, thereby facilitating the integration of results and evaluations of cumulative and system-wide benefits.
- Key uncertainties concerning management alternatives are addressed in an organized and efficient manner that accelerates shared learning for application to future management actions.
- Problem formulation, reflection, and continuous learning become institutionalized across agencies and stakeholder groups.

4. BUILDING THE INFRASTRUCTURE FOR CUTTING-EDGE SCIENCE

"In carrying out this section, the council shall make use of the best available science."
Water Code §85302(g)

The Delta Reform Action and the Delta Plan require the use of "best available science" in decision making that affects the achievement of the coequal goals (Box 1-2). The dynamic nature of the scientific enterprise should be recognized and mechanisms for including new knowledge or the latest data should be built into the process where appropriate. The Delta Science Plan pursues cutting-edge science – science that enables discovery, continuously improves and adds to the body of scientific knowledge. If applied correctly, adaptive management will take advantage of the improving body of scientific knowledge (Box 4-1).

Box 4-1 Building Capacity

As detailed in Chapter 5, formidable systemic hurdles exist in building the infrastructure for cutting-edge science. Without the essential tools and resources necessary to conduct the science, it is far from assured that the investments placed in achieving the outcomes envisioned in the Delta Plan and other major planning efforts to achieve the coequal goals will come to fruition. The Delta Science Program will work with others to assess possible mechanisms for enhancing:

- the ability to recruit and retain the next generation of scientists
- career-tracks for scientists in government
- access to continuing professional development opportunities, national professional conferences and forums for idea exchanges
- access to basic scientific tools such as such as scientific journals, up-to-date hardware and software, the role of universities in supporting science, modeling and professional development of scientists throughout the Delta Science Community (agencies, stakeholders, local government and consultants)

This chapter describes the infrastructure necessary to develop the science needed to inform complex decisions surrounding the management of the Delta. Science that informs policy and management decisions is built on a foundation of research, models, monitoring, analysis, synthesis, peer review and communication. At its most basic level, science is built on hypotheses that express ideas about how the world works. In a complex system like the Delta, hypotheses often take the form of conceptual models which can then be applied and tested through analyses and computer models. Models need data that come from research and monitoring. Synthesized research tells modelers how to improve algorithms that capture our understanding of processes and our ability to predict future conditions. Scientists use data analysis, modeling results and research findings to synthesize higher level understanding about how a system works.

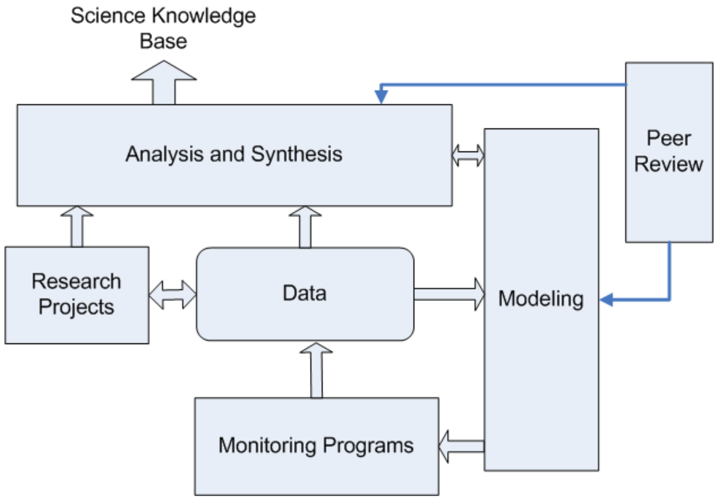

Figure 4-1. Conceptual relationships of the major elements of science infrastructure.

All of these elements are essential to building defensible and transparent science to support current and future decisions about the Delta. The Delta Science Program will work with other programs to further develop and integrate these components. The Delta Independent Science Board is charged with providing oversight of all Delta scientific research, monitoring, and assessment programs.

4.1 Prioritizing Research

Research in the Delta is done by universities, federal, State and local agencies, and private and nonprofit organizations. It ranges in scale from foundational (e.g., analyzing the diet of California clapper rails) to broad (e.g., developing linked models that provide information on discharge, flow paths, and other ecosystem attributes). However, research in the Delta should also address short-term management needs (e.g., what kinds of flow patterns are needed) and develop long-term comprehensive understanding (e.g., what is the role of known stressors and emerging contaminants on the productivity of tidal marshes). Research will include projects that may be risky to implement, but could have a big impact on the current state of scientific knowledge. To reconcile these differing needs, Delta research can be prioritized to use limited funding effectively through coordination among research programs.

Efforts to Build On:

- Multi-agency sponsorship of Delta Science Fellows solicitations
- Recent State Board workshops
- Research needs identified by BDCP
- Delta Science Program PSP process for identifying research priorities

Problem

Currently research priorities in the Delta are set on a program-by-program basis and are supplemented by academic contributions with minimal consideration to balancing short-term and long-term science needs. The status-quo approach to prioritizing research in the Delta is unlikely to result in a comprehensive reduction in the range of uncertainties needed to address the short-term management needs and longer-term management challenges of this rapidly changing system.

Objective

- A coordinated interagency process for choosing and prioritizing research that balances short-term, management-relevant research with research that anticipates emerging issues and enhances a comprehensive understanding of the Delta system over the long term

Actions

4.1.1 Develop and periodically update a shared list of research priorities for funding by agencies, institutions, and organizations. This will be maintained by the Delta Science Program.

4.1.2 The Policy-Science Team (Action 2.1) will set the “grand challenges”. The Science Synthesis Team (Action 2.2) will translate these overarching issues into a preliminary list of research topics, incorporating information on gaps and understanding gleaned from conceptual models. This list will then be open for public comment and discussed in a workshop setting by managers, stakeholders and other interested parties similar to the process currently used by the Delta Science Program. The final list will be approved by the Policy-Science Team and the Delta Independent Science Board. These activities will then be supported through direct funding and competitive grant processes.

4.1.3 Support Research.

4.1.3.1 **Competitive Research Grants.** The Delta Science Program will manage the solicitation process for selecting research projects. To increase efficiency of peer review, all funding agencies are invited to participate in this biennial process. Competitive proposals will be assessed on intellectual merit (provided by anonymous peer review and science review panels) and broader impacts (assessed by the Delta Science Synthesis Team and the responsible funding agency).

4.1.3.2 **Delta Science Fellows**. The Delta Science Program and California Sea Grant will jointly manage an annual Delta Science Fellows solicitation with potential research topics and funding invited from other organizations. The selection will follow the current procedure and be based on intellectual merit (provided by anonymous peer review and science review panels) and broader impacts (assessed by the Science Synthesis Team and the responsible funding agency).

4.1.3.3 **Rapid-response Research Grants**. To maintain flexibility and responsiveness of Delta science, some research funds are set aside for opportunistic research or to address unexpected events such as a major flood, earthquake, levee failure, or salt water intrusion into the Delta. These time-sensitive, innovative or exploratory research ideas will be managed similar to the National Science Foundation’s “RAPID” or “EAGER” grants. They will be funded through: a) focused solicitations where the scope of a project is generally known but it is open for proposals, or b) directed actions where the scope of the project is well defined and the appropriate project team has been identified for example, due to ongoing activities.

Expected Outcomes

- Research priorities build on ongoing research and address grand challenges and priority policy and management needs.

- Research is prioritized and funded efficiently.
- Knowledge gaps are identified and reduced.
- A feedback mechanism is established between new knowledge discovery (as summarized in the *SBDS*), reduction in uncertainty and risk in decision making, and setting the next cycle of study priorities.

See also

- Chapter 2 objectives
- Section 4.5 objectives

4.2 Monitoring and Associated Research

Environmental monitoring provides important scientific information that helps policy makers, managers, and the public address challenging environmental issues. The term "monitoring" covers a wide variety of sampling, analysis, measurement, and survey activities. It is often defined as "periodic or continuous collection of data (measured parameters) using consistent methods to determine the status (or condition) and trends of environmental or socio-economic characteristics." A comprehensive Delta monitoring program would follow environmental change as policy decisions are implemented and provide information to support adaptive management. It should include information about water supply, the ecosystem, and the Delta as place.

Efforts to Build On:

- Current and emerging regional monitoring programs
  - Delta Regional Monitoring Program
  - Regional Monitoring Program for San Francisco Bay (includes Suisun)
  - Interagency Ecological Program
- Delta Independent Science Board periodic reviews of monitoring programs that support adaptive management of the Delta
- Monitoring strategies
  - UMARP framework (Luoma at al. 2010)
  - Comprehensive Monitoring Program Strategy for California (CA WQMC 2010)

In the Delta, environmental monitoring has long played an important role and many long-term monitoring programs exist. For example, the Interagency Ecological Program (IEP) has been monitoring various kinds of fishes and ecological parameters (e.g., water flow, water quality, phytoplankton, zooplankton, benthic invertebrates) for decades. Additional programs soon will be added as part of the new BDCP, if approved, and the Delta Regional Monitoring Program; both programs are currently under development. None of the existing and planned programs capture or coordinate all Delta monitoring in the comprehensive manner needed to support the Delta Plan, BDCP, other plans, programs, and regulatory requirements. No shared strategy exists for Delta monitoring. We propose the development of a comprehensive monitoring strategy that will allow for better design, coordination, and integration of Delta monitoring. This plan would be based on a common monitoring framework and would build on recent efforts sponsored by the Delta Science Program, the California Water Quality Monitoring Council, and others. Inherent to this monitoring framework is the appropriate and timely assessment, reporting and publication of monitoring results.

Problem

A shared strategy for integrated monitoring in the Delta does not exist. Specific problems include: inadequate conceptual foundation (purpose), the lack of a comprehensive monitoring framework based on questions common to multiple agencies, lack of a common assessment approach, inadequate reporting on performance or environmental change, and inadequacies in data documentation (metadata), data management and data exchange. These same problems are associated with monitoring activities associated with data collection for water demand, above-ground storage, supply, conveyance, beneficial re-use and other water management monitoring related to Delta water supply. These difficulties in coordination are often compounded by inadequate resources for activities beyond monitoring itself (e.g. data quality assurance, data and metadata entry, systematic and regular analysis, and communication of results).

Objectives

- Develop a comprehensive inventory of monitoring in the Delta compiled from existing inventories but extended across a broader range of disciplines (e.g., compiled monitoring efforts by the Regional Water Quality Control Board, Region 5; State Water Quality Control Board, and others). This inventory will show where overlaps between monitoring programs exist and where gaps in data collection need to be filled.
- Assemble or develop conceptual models with the purpose of developing a common monitoring framework and prioritized questions or hypotheses. Existing conceptual models such as those built by the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) and the IEP Pelagic Organism Decline Investigations can be used as a resource. It may be necessary to construct additional models following a similar protocol.
- Identify a small number of Grand Monitoring Challenges. For example Luoma et al. (2010) identified four overarching Grand Monitoring Challenges:

    1. To understand how the ecosystem is changing in response to changes in infrastructure and water management actions that affect water supply reliability;
    2. To understand how the ecosystem is changing in response to ecosystem restoration activities and to changes in regulations and rulings to protect the environment;
    3. To understand how the ecosystem is changing in response to external forces (e.g., climate change, sea level rise, ocean processes);
    4. To understand how the ecosystem is changing in response to external changes in human activities like population growth, changes in land use, changes in agricultural runoff, and inadvertent importation of exotic species.

- Develop a framework that will provide a common focus for existing monitoring programs and monitoring plans. Elements of such a framework might include:

    1. A simple, overarching, common goal: track environmental change through time, in response to four Grand Monitoring Challenges.
    2. Identification of important environmental attributes (IEAs) that are likely to change; and the indicators, metrics and measurements that allows those attributes to be tracked and their change to be interpreted. These indicators would be developed by

coordinating a finite set of carefully selected data from across existing monitoring programs using a strict set of criteria for choices (e.g. Luoma et al. 2010).

3. Identify from this baseline data set a smaller set of SMART[5] targets against which to report on change.
4. Provide a strategy and resources for ongoing evaluation and interpretation (assessment) of monitoring data.
5. Provide a structure and approach for regular reporting of results to policy makers and the public.
6. Develop a system for appropriate, sustained data management across coordinated programs.

- Build a sense of common purpose among different institutional monitoring programs with their own missions.

Actions

4.2.1 Expand the development of standards for data compatibility and comparability among Delta monitoring programs.

4.2.2 Create a web-based information system describing all monitoring activities in the Delta, their products, and their nexus with regulatory requirements and management actions; assemble existing conceptual models and identify gaps relevant to Delta Monitoring.

4.2.3 Initiate a two-year comprehensive assessment to identify performance measures and construct a comprehensive and coordinated common monitoring framework. This will build from successful examples of monitoring design, earlier work on a unified monitoring, assessment and reporting framework for the Delta (Luoma et al. 2010), and published studies suggesting key performance measures (e.g. Cloern et al. 2012; Golet et al., in press; Luoma et al. 2010).

4.2.4 Use the assessment to design a one-year pilot program to test the framework, constraining the test either geographically, or to one “grand challenge.”

4.2.5 Use what was learned in the pilot program to build a full Unified Delta Monitoring program.

Expected Outcomes

- Development of a collaborative and comprehensive monitoring framework based on clear conceptual models.
- Regular, systematic reporting on Delta performance and environmental change to policy makers and the public.
- Regular feedback to adaptive management.
- The ability to leverage and share data among individual monitoring programs, resulting in lower costs for individual projects or programs.
- Improved availability of data for assessing outcomes of water management and habitat restoration actions outside of the SMART targets.
- Improved availability of data for use in regulations.

[5] S – specific, M – measurable , A – achievable, R – relevant, and T – time-specific

See Also

- Section 4.3, Data Management and Accessibility, for information about data interoperability.
- Section 4.7, Communication, for information about making monitoring information available online.

4.3 Data Management and Accessibility

During the last decade, collection of environmental data has increased exponentially for a variety of reasons and purposes. They include data collection for regulatory compliance and effectiveness monitoring, research to understand fundamental processes or cause-and-effect relationships, and landscape-scale status and trends monitoring. Increasing the availability of data, use of community data-driven models and coordinated research networks will accelerate knowledge discovery. Adaptive management for water supply reliability and resilient Delta ecosystems and economies will depend on the availability of reliable and usable data.

Efforts to Build On:

- California Technology Agency (http://www.cio.ca.gov/)
- Water Quality Monitoring Council, My Water Quality (http://www.waterboards.ca.gov/mywaterquality/)

Problem

Individual research groups collect data that are best suited to their respective requirements and mandates. This leads to fragmented data sets that are not conducive to data sharing, collaboration or synthesis. Research groups may also find that related data are not accessible or usable when they are collected because they are maintained with different standards and protocols, not sufficiently documented, or withheld for proprietary or legal reasons. Similar challenges are prevalent for data sets covering project-implementation activities (e.g., geospatial data about types of management interventions that are underway to meet performance targets). Collaborative science and data synthesis will face challenges unless data can be generated with agreed upon standards for interoperability and documentation, and with the resources and commitment to build an open community of science.

Objective

- Enable the Bay-Delta region's environmental and project-implementation data to be easily accessed, visualized and processed from diverse data management systems by agencies, scientists, stakeholders, academia and 'citizen scientists' (including K-12 schools) resulting in enhanced accumulation of knowledge

Actions

4.3.1 The Delta Science Program, the California Technology Agency and other key partners will co-host a summit on environmental and project-implementation data with national and international experts and leaders from federal, State, and local agencies, stakeholders, non-governmental organizations and academia. The summit participants will explore interoperability standards, web services, and resources needed for building a sustainable open-source science community accessing all Delta-wide data and visualization and data mining tools.

4.3.2 The Delta Science Program will work with other key partners to expand existing planning and tracking tools to inform management activities at the landscape scale.

Expected Outcomes

Following the Data Summit, the Delta Science Program in collaboration with others will:

- Assemble a dedicated team to explore the creation of a cyber-infrastructure for data collaboration throughout the Delta science community.
- Foster a commitment to work collaboratively on sharing, interoperability, and enhancing the knowledge of the Delta's natural resources.
- Develop a well-organized structure leading to collaborative activities between modelers with the ability for shared input data, shared scenarios and results, data streaming between different models and a modeling community that is at the forefront for informing water and environmental management. This structure should be a sustainable virtual network (with permanent funding) to allow data transfer, data mining and communication between scientists engaged on Delta issues.
- Create a community-developed standard for real-time connectivity to research and data streams in the Delta region.
- Organize a regional approach to cyber-infrastructure consisting of hardware, server platforms and storage, closely linked with national Big-Data resource opportunities.
- Develop web services enabling community data access, integration, visualization and display.
- Create an open user access for researchers, agencies, scientists, stakeholders, academia and 'citizen scientists' (including K-12 schools)

4.4 Shared Modeling

Models represent a repository of current understanding of processes and cause-effect relationships. They can be conceptual or numerical. Models can be used to develop insights, often in a transparent, visual and defensible manner. Models are needed for adaptive management and planning. They summarize and integrate our understanding of systems and processes with greater precision and transparency (Delta Science Program Invited Panel 2012).

A new era is dawning of open computer codes, cloud computing, data accessibility, data visualization, and virtual networks of scientists supporting and advancing models. The Delta modeling community embraces these changes and seeks to be at the forefront of these developments for addressing environmental issues. Models will continue to be a central part of our understanding of how the Delta functions as a system and be a key component in the design, management, and performance assessment of projects and actions.

Problem

Currently, modeling needed to explore anticipated outcomes of management alternatives in the Delta takes place at a number of different agencies, academic institutions, and private entities. Further, many contemporary questions require exchange of results between several discipline-specific models. Modeling needs to be done in a more interdisciplinary way to accelerate knowledge discovery, avoid duplication of efforts and support diverse modeling approaches.

> Modeling is an essential and inseparable part of all scientific, and indeed all intellectual, activity. How then can we treat it as a separate discipline? The answer is that the professional modeler brings special skills and techniques to bear in order to produce results that are insightful, reliable, and useful. Many of these techniques can be taught formally, such as sophisticated statistical methods, computer simulation, systems identification, and sensitivity analysis. These are valuable tools, but they are not as important as the ability to understand the underlying dynamics of a complex system well enough to assess whether the assumptions of a model are correct and complete. Above all, the successful modeler must be able to recognize whether a model reflects reality, and to identify and deal with divergences between theory and data. (Silvert. 2001)

Objectives

- Accelerated discovery of knowledge about how the Delta system functions through development of a mechanism that supports models used for today's management actions, while researching and testing models for the future.
- Established community models that are accessible, transparent, sustained by multiple sources and encapsulate the current knowledge of the Delta system.

Actions

4.4.1. Work with the California Water Environment Modeling Forum (CWEMF) to develop a framework for collaborative community modeling. This will include the mechanisms for agency, academic, non-governmental organization, consultants, public water agency and local government staff to contribute to model development and generate model projections of future outcomes.

4.4.2. Develop, update and maintain conceptual models to identify the current state of knowledge, identify gaps in understanding, contribute to the identification of research priorities and support adaptive management planning and implementation. The Delta Science Program will be the primary repository for these conceptual models.

4.4.3. The Delta Science Program will collaborate with other agencies, academic institutions and stakeholders to develop landscape-scale conceptual models for the six priority ecosystem restoration areas identified in the Delta Plan

4.4.4. Continue to support high-priority model development and refinement through research grants, fellowships, workshops, seminars and conferences.

Expected Outcomes

- Enhanced collaborative activities between modelers, shared input data, shared scenarios and results, data streaming between different models and a modeling community that is at the forefront of predicting the outcomes of alternative water and environmental management scenarios

- Accelerate the transfer of best available science to inform management actions in support of water supply reliability and Delta ecology
- Reduce the resources required for initial model set-up and application, thereby increasing the time and resources modelers have available to conduct synthesis, interpretation, uncertainty analyses, information transfer, improvement of model algorithms and development of the next generation of models to address Delta issues

Efforts to Build On:

California Water and Environmental Modeling Forum– The CWEMF mission is to increase the usefulness of models for analyzing California's water-related problems. CWEMF carries out this mission by:

- facilitating an open exchange of information on California water issues;
- resolving technical disagreements in a non-adversarial setting; and
- ensuring that technical work continues to take into account the needs of stakeholders and decision makers.

Since 1994, CWEMF has initiated and managed a number of impartial peer reviews. These peer reviews:

· Document model strengths and weaknesses
· Suggest improvements
· Assess the suitability for intended applications

CWEMF has helped build the modeling community by bringing modelers together from California and across the country at its annual meetings.

4.5 Synthesis for System-wide Perspectives

The central challenge in understanding a system as large and complex as the Delta is integrating information about the components into a coherent whole. Decades of research and monitoring have yielded tremendous volumes of data, but too often, appropriate methods to integrate across multiple data sources are lacking. The financial resources required to meet this mandate have yet to be agreed upon and allocated (See Appendix 2: Funding Delta Science). Leadership and mechanisms for bringing together researchers from agency, stakeholder and academic communities are needed to foster scientific synthesis to accelerate knowledge discovery and its application in policy development and adaptive management in the Delta.

Problem

As highlighted by the recent National Research Council study, synthesis is the single most important need for developing Delta science. Currently, an ongoing effort for synthesizing scientific understanding of the Delta system does not exist. Without mechanisms and protocols for conducting ongoing synthesis, new insights and better understanding of the Delta system and its communication is delayed.

Objectives

- Synthesis results communicated to all levels (among policy makers, scientists, managers, stakeholders and other interested parties) to promote new knowledge discoveries that contribute to achieving the coequal goals
- Analyzed and synthesized data that develop new insights and a better understanding of the system
- Delta community researchers brought together through synthesis activities to foster relationships, integrate research results and develop a shared understanding of Delta functions and the uncertainty

Efforts to Build On:

- *State of Bay-Delta Science 2008*
- Synthesis products in *San Francisco Estuary Watershed Science*
- National Center for Ecological Analysis and Synthesis model
- IEP Pelagic Organism Decline
- Delta Science Program Workshops
- IEP Management Analysis and Synthesis Team
- Estuary and Wetlands Monitoring Portal and Integrative Health of the Estuary Webtools

Actions

4.5.1 Establish mechanisms and protocols for conducting ongoing syntheses through shared processes (e.g., among Delta Science Program and BDCP, SWRCB, and/or OCAP). Four mechanisms are:

1. Invited white papers/journal articles by small groups of authors
2. Expert workshop panels similar to the CALFED Science Program Ammonia/Ammonium Workshop
3. Delta Collaborative Analysis and Synthesis (DCAS) – Focused teams with regional and national interdisciplinary experts that conduct in-depth analyses over a period of one year resulting in peer-reviewed journal articles or white-papers that summarize current knowledge or bring fresh perspectives to a major issue. This approach is modeled after the National Center for Ecological Analyses and Synthesis (NCEAS) and has been used successfully by IEP.
4. Delta Independent Science Board reviews of research and monitoring processes and approaches that support adaptive management of the Delta

4.5.2 DCAS projects will be initiated by annual calls for proposals on high-priority synthesis topics identified by the Science Synthesis Team. Successful proposals will require involvement of researchers from multiple institutions and representing diverse perspectives. The findings will be subjected to rigorous peer review. Funded projects will include a member of the Delta Science Program with relevant technical expertise.

4.5.3 The Delta Science Program will facilitate the work of the Science Synthesis Team and Focused Science Synthesis Teams (Action 2.2 and 2.3).

Expected Outcomes

- Accelerated knowledge discovery about the state of the Delta ecosystem.
- Diverse synthesis publications including *SBDS,* scientific journals articles (e.g., articles in *San Francisco Estuary and Watershed Sciences*) and Delta Science Program White Papers.

- A culture of interdisciplinary and collaborative scientific exploration that enhances the understanding of a dynamic system.
- A better understanding about how the Delta responds to change induced by management actions, climate change, natural disasters and chronic stressors.

4.6 Independent Scientific Peer Review and Advice

Making well-informed decisions regarding the use and protection of natural resources requires that we fully consider and employ the most reliable and accurate scientific information and judgment available. Calls for inclusion of "the best available science" and independent analyses or review of environmental policy and decision making repeatedly are heard from Congress, the Executive Branch, and other interests. We agree that such participation by the nation's scientific community in the form of independent scientific review can contribute to better-informed environmental policy and decision making.'[6]

The peer review process uses independent scientific experts and plays a key role in determining what is "best available science." Peer review increases the credibility of scientific information and helps scientists improve the quality of their work. Peer review should be an integral and expected part of the science conducted in the Delta. A culture of constructive ideas and innovation to improve the quality and applicability of science should be fostered. The Delta Science Program's policy and procedures for independent peer review of processes, programs, plans and products are included in Appendix 1. Peer review is also a key part of research grant funding programs. In addition to providing feedback on scientific integrity, well-designed peer review processes provide independent perspectives and judgments from experts in the subject area. High-quality peer reviews are conducted in a manner so that they are objective, rigorous and transparent.

A companion to peer review is independent scientific advice. Projects and programs might often benefit from the active participation of an independent scientist or scientists when they are faced with challenging technical or scientific issues. In these cases, an independent entity can help by identifying experts with experience in the appropriate disciplines who can provide advice at key points in planning, implementation, or evaluation. Similarly, the advice of the Delta Independent Science Board may be requested during the planning stages of a project, synthesis activity or program.

Efforts to Build On:

- Draft Delta Science Program Policy and Procedures for Independent Scientific Review (February 2013)
- Delta Science Program Proposal Solicitation Package review process
- National Academies' review approach and role
- Delta Independent Science Board reviews

[6] Gary K. Meffe, P. Dee Boersma, Dennis D. Murphy, Barry R. Noon, H. Ronald Pulliam, Michaele . Soule and Donald M. Waller. Independent Scientific Review in Natural Resource Management. Conservation Biology Volume 12, No. 2, April 1998

Scientific peer review or advice can be set up in several ways. The entity conducting the review, number of reviewers, the type of process (e.g. panel meeting, independent written reviews), and the length of time for the review can all be adjusted to fit the complexity, level of scientific uncertainty, importance of the subject, and available funding. In its broadest sense, peer review includes the review functions of the Delta Science Program, the Delta Independent Science Board and the National Research Council for external reviews of scientific progress on a 5 or 10-year cycle or for matters likely to set national precedent. Figure 4.6-1 shows how these review functions are related.

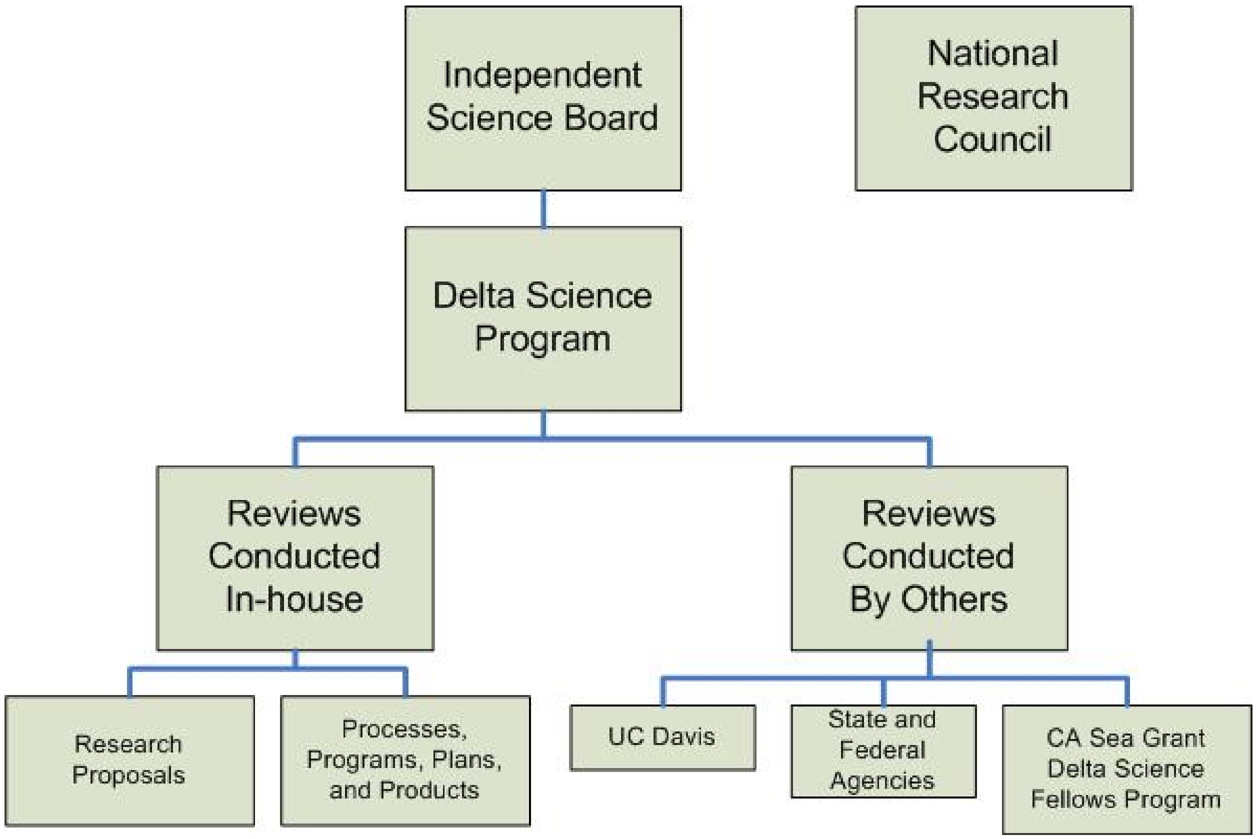

Figure 4.6-1 Structure of reviews conducted under the Delta Science Plan.

The delta Science Program will take a leadership role in the review of proposals, processes, programs, plans, and products. Reviews may be conducted in-house organized by Delta Science Program staff or by other agencies or institutions with Delta Science Program tracking and guidance. The Delta Independent Science Board's review responsibilities are defined in statute and include periodic reviews of the "scientific research, monitoring, and assessment programs that support adaptive management of the Delta" (Water Code §85280 (a)(3)). Upon request, the National Research Council may be asked to review issues with broad implications for federal agencies or of importance to restoration or water management efforts nationally.

Problem

Interdisciplinary environmental research projects and science-based planning and management documents in the Delta are initiated by federal and State agencies, academia, non-governmental organizations, water contractors and consultants. Research results and science-based planning and management documents that do not undergo scientific peer review or utilize independent scientific advice may result in unchecked assessments or scientific information developed with a pre-determined outcome in mind. Decision makers and environmental managers require peer-reviewed, defensible, robust science for managing the Delta resources; however, a standard level of peer review is not yet widely applied in the Delta. Research should never be funded without adequate and independent peer review.

Objectives

- Application of the criteria for best available science, information and data to assist management and policy decisions consistent with the Delta Plan's criteria for best available science
- Clearly documented and effectively communicated independent scientific peer review and advice processes and information to foster improved understanding and build trust in decision-making processes
- Scientific information resulting from a peer review process is incorporated into sound water and environmental decision making

Actions

4.6.1 Adopt a well-defined, transparent and widely accepted process for conducting scientific peer review that is consistent across programs and can be applied to research, planning and management documents in the Delta.

4.6.2 Seek direction from the Delta Independent Science Board on its role and level of engagement for each four-year cycle of Action Agenda and *SBDS*

4.6.3 Refine existing processes and align with other agencies and groups to establish consistent standards in conducting scientific peer review, with documented exceptions such as the U.S. Geological Survey, which is widely regarded as a 'gold-standard'.

4.6.4 Develop a response mechanism to peer review of programs, reports or actions that address each major point in the review, how the concern is being addressed, and the reasons for not being able to address any issue.

4.6.5 The Delta Science Program will establish and maintain a repository of the charges to the review panels, the findings and responses to findings of scientific peer reviews.

Expected Outcomes

- An established transparent collaborative peer review process that produces the best science, clearly outlining assumptions and limitations. The best science is also reputable as it goes through peer review conducted by active experts in the applicable field(s) of study.
- Where necessary, a 'fast-track' peer review/advice process to address urgent issues.

4.7 Communication

"You can't blame them for not knowing the jargon – it's not their job. Why would anybody put up money for something they don't understand?" –Alan Alda

Communication is essential to building the Delta science community, building understanding of the issues, and delivering important science messages to the public, managers, policy makers and stakeholders. In fact, it is the keystone for transforming information into knowledge, and knowledge into action. Communication takes many forms from the various digital media, publications, news articles, seminars, workshops, and conferences to water cooler conversations. The concept of "best available science" is predicated on the way that scientific information is reviewed and communicated. No matter how important, scientific information that is not communicated is not "available". This section addresses how scientists communicate with each other, and to managers, policymakers and the public.

A broad range of avenues exists for science communication including seminars, the biennial Bay Delta Science and State of the Estuary conferences, the Delta Science Program's *Science News* newsletter and the *San Francisco Estuary and Watershed Science* online journal. However, the world of communication is dynamic and continually offering new opportunities for improving the way scientists speak to each other and the world.

Efforts to Build On:

- Delta Science Program's *Science News*
- *San Francisco Estuary and Watershed Science*
- IEP's online calendar (http://www.water.ca.gov/iep/activities/calendar.cfm)
- *Pulse of the Delta*
- *Pulse of the Estuary*
- *My Water Quality*
- IAHR – Rivers-list (http://riverslist.iahr.org/)
- *The State of Bay-Delta Science*
- *Bay-Delta Science Conference*
- *State of the Estuary Conference*
- *Estuary Newsletter*

Problem

Important scientific information is often underutilized because it is not effectively communicated. Better science communication is needed to build the Delta science community and to effectively inform policy and management decisions. Complex scientific information needs to be distilled and presented in a form that policy and management decision makers can understand.

Objectives

- Improved communication of science within and outside of the science community through current communication mechanisms and the development and application of innovative communication tools
- Regular exchange of new scientific information with policy and management communities
- A public inspired about the role of science in managing California's resources through major scientific breakthroughs, virtualization of alternative futures and explanations of major storm or seismic events

Actions

- 4.7.1 Expand science communication (e.g., outreach to the State Legislature, distilled versions of synthesis documents).
- 4.7.2 Develop information sharing with other large ecosystem management programs in the U.S. and internationally.
- 4.7.3 Facilitate the development of data visualization tools and virtual landscapes under various management scenarios.
- 4.7.4 Investigate innovative means of communication including enhancing science blogs, virtual communities such as moderated online discussion sites and use of social media (for example, Twitter or Facebook).
- 4.7.5 Establish and maintain the Delta Science Program website to include summaries of policy and management relevant science.
- 4.7.6 Investigate science communication tools to aid scientific discovery for the broader public and K-12 students.
- 4.7.7 Use forums such as conferences or workshops to discuss new research findings, explore new initiatives and invite the Policy-Science Team to convene media events around these gatherings.

Expected Outcomes

- Enhanced Delta science communication.
- New forms of communication that accelerate scientific discovery and improve science-policy and science-management communication.
- Managers interested in developing scientific understanding and communicating science when describing their actions.
- Managers able to apply current scientific results to ongoing management issues relevant to achieving the coequal goals.
- A more informed public.

See Also

- Chapter 2, Organizing Science to Inform Policy and Management
- Section 4.5, Synthesis for System-wide Perspectives

5. THE FUTURE OF DELTA SCIENCE

Considerable resources have been dedicated for decades to conduct monitoring and research focused on specific agency mandates and responsibilities. While some science priorities are coordinated across individual agencies, such as through the Interagency Ecological Program, insufficient resources are pooled to focus on overarching and often controversial questions common to multiple agencies, but outside the jurisdictional boundaries of any single one. Furthermore, as identified in a recent report by the Public Policy Institute of California (Gray et al. 2013), science coordination efforts among agencies with different cultures have proven inefficient, especially for funding science.

Resources for science are a prerequisite for adaptive management and informed decision making. The Delta Science Program has the responsibility for bringing together the key players who can act on science-based solutions to address interactive effects of multiple stressors on the ecosystem and for finding science-based solutions to often conflicting goals. It will take a joint effort by the scientific community to find partnerships and support to build the resource capacity to implement strategic directions outlined in the Delta Science Plan and earlier science planning documents (e.g., Vance 2005; CalEPA Steering Committee for Science 2007; Ocean Science Trust 2008). Champions are needed in the legislature, Governor's Office, and control agencies to restore and advance the capacity of scientists working in agencies to fulfill their duties. Adequate resources are required to build the infrastructure for cutting-edge science (Ch 4) for the entire scientific community contributing to one or more of the "grand challenges" facing the Delta.

Formidable systemic hurdles exist in developing the infrastructure for cutting-edge science described in Chapter 4. The science and management communities together will need to dedicate considerable effort to communicate to funding decision makers (the legislative and executive branches of government, as well as the beneficiaries of embedding science into the water management and ecosystem restoration action plans) how relatively small, yet sustainable investments in science can generate disproportionately larger pay-backs in terms of operational efficiencies, less litigation, and better environmental and social outcomes. Improvements in the science infrastructure are required to gain access to even the most basic tools required by scientists to inform the multi-billion dollar effort to achieve the coequal goals. Without the essential tools and resources necessary to conduct the science, it is far from assured that the investments placed in achieving the outcomes envisioned in the Delta Plan and other major planning efforts to achieve the coequal goals will come to fruition. The reports referenced above are consistent in their recommendations and apply to this day:

- Increase the ability to recruit, retain, and equitably remunerate scientists
- Provide scientists with access to continuing professional development opportunities, such as scientific journals, up-to-date hardware and software, and national professional conferences and forums for idea exchanges
- Improve linkages and opportunities for interactions between academia and science serving specific ecosystem and water management needs (e.g., research partnerships).

The Delta Science Program will expand its capacity to facilitate and coordinate Delta Science Plan actions to remain relevant, flexible and with an emphasis in serving essential synthesis and review functions for the larger Delta science and management communities. This will include the ability to supplement core career staff with 'rotators' modeled on the National Science Foundation, whereby scientists from other organizations (including federal agencies, State agencies, local government, universities, stakeholders and non-governmental organizations) may spend a fixed term within the Delta Science Program to help implement the Action Agenda, coordinate updates to the *SBDS* or participate in other responsibilities of the Delta Science Program. The salaries of rotators may be covered by the Delta Science Program during the period of appointment. The rotators ensure a continuous infusion of new ideas, ensures the staff that facilitate '*One Delta, One Science'* are representative of the community the Delta Science Program serves and builds trust that the processes used are open and transparent.

Objectives

- Generate an appropriate funding base for fulfilling the vision of an open Delta science community that builds a shared state of knowledge with the capacity to adapt and inform future water and environmental decisions
- Improve the organizational structure for science and create funding efficiencies via pooled resources to address questions beyond the limited mandates of individual agencies
- Reform the underlying capacity challenges to conduct science for ecosystem and water management, such as the ability to recruit and retain scientists into state service, as well as providing them with the essential tools required to fulfill their duties
- Apply a mix of sustainable funding models for science that are clearly connected to implementation and adaptive management principles

Resources Needed

Implementation of the Delta Science Plan relies on the cooperation and partnership of the Delta policy, science and management communities. Implementation also relies on the capacity of the Delta Science Program to provide the leadership and skill sets to facilitate and support these shared efforts. Adequate resources are need for the Delta Science Program to succeed in facilitating the development of scientific information and synthesis crucial for managing the Delta system. That body of knowledge must be broadly accepted, relevant, authoritative, properly integrated and communicated to Delta decision makers, agency managers, stakeholders, the scientific community and taxpayers. The Delta Science Program anticipates growing substantially to be capable of supporting the objectives, actions and expected outcomes described in the previous chapters of the Delta Science Plan:

- Implementing the Delta Science Strategy
- Organizing Science to Inform Policy and Management (ongoing science synthesis, coordination and communication with policy and management audiences)
- Adaptive Management for a Complex System (consultations, consistency determinations, planning and coordination of adaptive management across programs)
- Building the Infrastructure for Cutting-Edge Science (prioritizing research, monitoring and associated research, data management and accessibility, shared modeling, synthesis for system-wide perspectives, independent scientific peer review and advice, and communication)

Current funding is limited to a small percentage of the services the Delta Science Program is expected to provide and mostly focused on support for existing research grants and fellowships, organizing workshops, expert panels, and review, as well as support for the Delta Independent Science Board. With the approval of the Delta Plan and its accompanying rule-making package, progress toward either one of the coequal goals cannot be sufficiently informed or achieved without linking funding levels to the number and complexity of projects, programs, and plans that require science input and other science needs. A linkage between funding and complexity of tasks to achieve expected results could be established by allocating a fixed percentage of habitat restoration and water conveyance costs toward implementation of the Delta Science Plan to insure that the trends over time toward environmental targets can be adequately quantified and communicated, the knowledge base can be applied in adaptive management, and new research findings, methods, and tools can continually improve best available science.

Glossary

[Under construction]

Includes all relevant terms in Delta Plan but also addresses contentious issues as definitions of science and scientists.

References

Cloern, J. E., N. Knowles, L. R. Brown, D. Cayan, M. D. Dettinger, T. L. Morgan, D. H. Schoellhamer, M. T. Stacey, M. van der Wegen, R. W. Wagner, and A. D. Jassby. 2011. Projected evolution of California's San Francisco Bay-Delta-River system in a century of climate change. PLoS ONE 6:e24465

Collins English Dictionary. http://www.collinsdictionary.com/dictionary/english. Accessed June 2013.

Delta Science Program Invited Panel 2012

Gray, Brian, B. Thompson, E. Hanak, J. Lund, J. Mount. 2013. Integrated Management of Delta Stressors: Institutional and Legal Options. Public Policy Institute of California. http://www.ppic.org/content/pubs/report/R_413BGR.pdf. Accessed June 2013.

Luoma, S.N., R. Fujii, B. Herbold, M. Johnson, W. Kimmerer, A. Mueller-Solger, P. Smith, D. Austin. 2010. Framework for a Unified Monitoring Assessment and Reporting Program (UMARP). Report to the Delta Science Program in 2010. Available from first author at snluoma@ucdavis.edu.

National Research Council, 2012. Sustainable Water and Environmental Management in the California Bay-Delta. ISBN 978-0-309-25619-3

Ocean Science Trust. 2008. Linking the Academic Community and Water Quality Regulators. A Report Prepared for the California Ocean Science Trust By T.C. Hoffmann & Associates, LLC. http://calost.org/pdf/resources/ost-products/reports-prepared-for-ost/LinkingAcademics_FullReport.pdf. Accessed June 2013.

Steering Committee for Science. 2007. The Quality and Role of Science in Cal/EPA. Report to the Secretary from the Steering Committee for Science California Environmental Protection Agency. http://www.calepa.ca.gov/publications/Reports/2007/SCSJuly.pdf. Accessed June 2013.

Vance, William A. 2005. Role of Science and Engineering in Decision-Making within the State and Regional Water Boards. State Water Resources Control Board. http://www.waterboards.ca.gov/publications_forms/publications/general/docs/sciencereport.pdf. Accessed June 2013.

Appendix 1: Draft Policy and Procedures for Independent Scientific Review (February 2013)

Background

As part of its mission to provide the best available scientific information to guide management and inform policy making in the Bay-Delta system, the Delta Science Program promotes and provides independent scientific review of processes, programs, plans, and products. The policies and procedures below describe how independent scientific review provided by the Delta Science Program will be conducted.

Decision to Provide Review

Independent scientific review may be requested by any agency or other interested party. The review will focus on one or more written documents. The Delta Science Program's decision to provide a review will depend on other (competing) commitments of the Delta Science Program and the relevance of the review with respect to the goals and objectives of it and Delta Stewardship Council. Furthermore, the Delta Science Program will only agree to provide a review if there is sufficient funding available for the review, if there is sufficient time available to complete the review and deliver a report, if the apposite document is complete and ready for review[7]. The ultimate decision to provide a review rests with the Lead Scientist for the Delta Science Program.

Planning Meetings

Meetings to plan for a review may be held with members of the requesting party, authors of the document(s) subject to review, and interested agency/stakeholder representatives prior to initiation of the review. Participants in a Review Planning Group composed of those parties may communicate their expectations for the pending review, will provide input on the Charge to the Panel, may consider the review schedule and panel-member composition, and may provide pertinent background documents or other instructional materials for the review through the Delta Science Program.

Charge to the Panel

Charge questions are developed with input from the Review Planning Group. The Lead Scientist has the final responsibility for the Charge to the Panel. Charge questions or tasks will be

[7] Review of draft documents, like final documents, is appropriate provided they are complete and ready for review. In contradistinction, review of partial documents, whether final or draft, is generally inappropriate.

technical (or analytical) in nature, and will not require policy prescriptions from the review panel (however, it is recognized that responses and other information in a review report may be used in future decision-making by resource managers and policymakers.) Accordingly charge questions and tasks will be crafted to best draw applicable guidance, but not to solicit explicit policy recommendations or prescriptions.

The scope of the Charge to the Panel will include background information (including the legal, regulatory, and management background necessary to set the full policy context for the Charge to the Panel), questions and tasks for the panel, a description of the role of the panel and rules for its deliberations and the form and scope of the review product, and a schedule of deliverables.

Independent Science Review Panel

Panels will include no fewer than five members. Selection of Independent Scientific Review Panel members will consider input from the Review Planning Group. The selection of panelists will consider an individual's standing in the scientific community, expertise in disciplinary areas and with technical skills relevant to the documents and technical issues subject to review, and absence of a demonstrated conflict of interest. A panel as a whole is expected to have a broad range of expertise including some familiarity with the geographic region, physical processes, policy issues, ecosystems, and species-specific aspects of the review.

Materials for Review

Materials to be reviewed by the Independent Scientific Review Panel include the review document or documents, and pertinent background materials. Background materials will not be limited to the (specific) technical questions and issues in the Charge to the Panel, but can include documents describing the legal and regulatory context of the review questions and tasks, and consider the management implications of materials provided to the review panel and relevant to the review report. Other study materials or information identified as pertinent to the review introduced by panel members during the panel meeting can be used at the discretion of the panel. Panels are encouraged to request any additional information or other materials that might facilitate their deliberations and report production. Stakeholders and other interested parties may submit materials to be considered by the review panel; however, final decisions relating to any materials to be provided to the review panel rest with Lead Scientist.

Communication with the Panel

No direct communications by interested parties, including the agency that produced the document subject to review, with panel members on issues pertinent to the review during the review period should be made without the knowledge and consent of the Delta Science Program. The panel may be asked to disregard any communication received without the knowledge and consent of the Delta Science Program.

Public Meetings

The review process will be open and transparent to the extent practicable. Unless there are compelling reasons to do otherwise, each independent scientific review will have a public meeting. While the review panel will deliberate in camera to develop their recommendations, the opportunity for public comment will be provided as a part of any open (public) sessions of each review.

Public Communication

A webpage accessible through the Delta Stewardship Council and Delta Science Program website will present background information on each independent Scientific Review undertaken, meeting agendas, membership of panels convened, all background materials and documents to be reviewed, and the final review document. To the extent possible, all materials for panel review will be posted on the website at the same time that they are provided to the panel; at a minimum, 10 days in advance of the first meeting of the review panel. Scheduling and other information about that meeting and the availability of review report(s) will be sent to the Delta Stewardship Council's list serve.

The Delta Science Program will compile and retain a record of the review, including the materials described above as well as any additional materials provided to the panel including presentations from the public sessions of meetings.

Panel Report(s)

The Delta Science Program may suggest grammatical or formatting edits of a draft report to improve it, but will not otherwise substantively amend a review panel report. The content, substance, and recommendations of a review panel report are those of the review panel, not the Delta Science Program or Delta Stewardship Council. The Delta Science Program will post the report after approval of the panel. The Delta Science Program may provide a courtesy copy of the report to the agency that produced the materials subject to review in advance of posting the report. If the agency that produced the materials subject to review chooses to develop a written response, the response will be posted along with the review at the time it becomes available.

Appendix 2: Funding Delta Science

[This may be prepared under separate cover]

[This chapter needs an in-depth discussion about funding Delta science as a whole – not merely the Science Program housed at the DSC. It takes time and effort to develop shared work plans with partner agencies, align common approaches, and develop sustainable funding for specific mandated activities and those going beyond individual jurisdictional boundaries. An example would be the stewardship of the California Aquatic Resources Inventory.]

Appendix 3: Adaptive Management Guidelines

The following are suggested guidelines for each of the nine steps of the Delta Plan adaptive management framework to help proponents incorporate adaptive management into their project plans.

1) Define/Redefine the Problem

- Project proponents and stakeholders articulate the problem statement as a group.
- Link management problem with relevant scientific knowledge and conceptual models.
- Project proponents identify funding source(s) for carrying out the adaptive management process as part of the certification of consistency with Policy GP 1 of the Delta Plan.

2) Establish Goals and Objectives

- Articulate specific objectives.
- Place objectives into larger landscape/watershed context.
- Through early engagement with the Delta Science Program Adaptive Management liaison(s), develop shared understanding of the limitations and opportunities of goals and objectives based on conceptual models.

3) Model Linkages between Objectives and Proposed Action(s)

- Use conceptual and quantitative models (including landscape-scale and community models developed under the Delta Science Plan Action 4.4.3) to develop hypotheses, determine the range of potential outcomes (benefits and risks) of alternative actions, and determine what information is needed to test hypotheses, analyze results, and reduce critical uncertainties.

4) Select Action(s) and Identify Performance Measures

- Use the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Action Evaluation Procedure and accompanying worksheets as an organizing tool for evaluating project objectives and initial range of actions.
- Articulate expected benefits and risks of actions designed to meet project objectives.
- Select adequate and realistic performance measures based on desired outcomes, project conceptual model and simulation models.
- Ensure consistency and integration with system-wide performance measures.

5) Design and Implement Actions

- Use the conceptual models and Action Evaluation Procedure to evaluate various designs.
- Consider the range of outcomes under various alternative actions (“alternative futures”) through modeling and expert opinion evaluation.
- Consider effects on other current actions and determine future actions that could be precluded by this action.
- Design action(s) and appropriate monitoring approach to reduce uncertainty, test model predictions, and integrate into related research programs.

6) Design and Implement Monitoring

- Based on the models and tiered management questions associated with the project, determine the most appropriate statistical design of the proposed monitoring program, including linkage

to companion research effort, modeling, performance measures and system-wide monitoring, including the collaborative and comprehensive Delta monitoring program (Action 4.2.3.
- Document other data sources to be used in assessment.
- Develop funding source and identify responsible entities for monitoring.
- Develop data management plan for project.
- Collect and share data via an open Delta cyber-infrastructure (Action 4.3.1).

7) Analyze, synthesize and evaluate
- Analyze data and use shared mechanisms and protocols for synthesis (Actions 4.5.1) to learn the effects of the action taken.
- Evaluate progress based on performance measures and utilize independent scientific peer review protocols to check the integrity of the science (Actions 4.6.1 - 4.6.3).

8) Communicate Findings
- Communicate current understanding through science-management team discussions and communication tools (Actions 4.7.1 - 4.7.4)
- Provide adequate opportunities for all interested parties to engage in process.

9) Adapt
- Re-define the problem being addressed.
- Adjust the goals and objectives.
- Re-calibrate models with new data, as appropriate.
- Adjust management actions if necessary, based on outcomes and responses to implementation in Step 5.
- Evaluate robustness of management, regulatory, and policy structures to implement change and adaptation on this or future related projects.

Appendix 4 – Best Available Science Definition in the Delta Plan Rule Making Package

For reference: From the Delta Plan

Best Available Science

The Delta Reform Act requires the Council to make use of the best available science in implementing the Delta Plan. Best available science is specific to the decision being made and the time frame available for making that decision. Best available science is developed and presented in a transparent manner consistent with the scientific process (Sullivan et al. 2006), including clear statements of assumptions, the use of conceptual models, description of methods used, and presentation of summary conclusions. Sources of data used are cited and analytical tools used in analyses and syntheses are identified. Best available science changes over time, and decisions may need to be revisited as new scientific information becomes available. Ultimately, best available science requires scientists to use the best information and data to assist management and policy decisions. The processes and information used should be clearly documented and effectively communicated to foster improved understanding and decision making.

Steps for Achieving the Best Science

Science consistent with the scientific process includes the following elements:

- Well-stated objectives
- A clear conceptual or mathematical model
- A good experimental design with standardized methods for data collection
- Statistical rigor and sound logic for analysis and interpretation
- Clear documentation of methods, results, and conclusions

The best science is understandable; it clearly outlines assumptions and limitations. The best science is also reputable; it has undergone peer review conducted by active experts in the applicable field(s) of study. Scientific peer review addresses the validity of the methods used, the adequacy of the methods and study design in addressing study objectives, the adequacy of the interpretation of results, whether the conclusions are supported by the results, and whether the findings advance scientific knowledge (Sullivan et al. 2006).

There are several sources of scientific information and tradeoffs associated with each (Sullivan et al. 2006, Ryder et al. 2010). The primary sources of scientific information, in a generalized ranking of most to least scientific credibility for informing management decisions, include the following:

- Independently peer-reviewed publications including scientific journal publications and books (most desirable)
- Other scientific reports and publications
- Science expert opinion

- Traditional knowledge

Each of these sources of scientific information may be the best available at a given time and contain varying levels of understanding and uncertainty. These limitations should be clearly documented when scientific information is used as the basis for decisions.

Guidelines and Criteria

There have been several efforts to develop criteria for defining and assessing best available science. In 2004, the National Research Council Committee on Defining the Best Scientific Information Available for Fisheries Management prepared a report (National Research Council Report) that concluded guidelines and criteria must be defined in order to apply best available science in natural resource management (National Research Council 2004). Major findings and recommendations included establishing procedural and implementation guidelines to govern the production and use of scientific information. The guidelines were based on six broad criteria: relevance, inclusiveness, objectivity, transparency and openness, timeliness, and peer review. Best available science for proposed covered actions and for use in the Delta Plan should be consistent with the guidelines and criteria in Table 1A-1. These criteria were adapted from criteria developed by the National Research Council. Proponents of covered actions should document their scientific rationale for applying the criteria in Table 1A-1 (i.e., the format used in a scientific grant proposal).

Table 1A-1

Criteria for Best Available Science

Criteria	Description
Relevance	Scientific information used should be germane to the Delta ecosystem and/or biological and physical components (and/or process) affected by the proposed decisions. Analogous information from a different region but applicable to the Delta ecosystem and/or biological and physical components may be the most relevant when Delta-specific scientific information is nonexistent or insufficient. The quality and relevance of the data and information used shall be clearly addressed.
Inclusiveness	Scientific information used shall incorporate a thorough review of relevant information and analyses across relevant disciplines. Many analysis tools are available to the scientific community (e.g., search engines and citation indices).[a]
Objectivity	Data collection and analyses considered shall meet the standards of the scientific method and be void of nonscientific influences and considerations.
Transparency and openness	The sources and methods used for analyzing the science (including scientific and engineering models) used shall be clearly identified. The opportunity for public comment on the use of science in covered actions is recommended. Limitations of research used shall be clearly identified and explained. If a range of uncertainty is associated with the data and information used, a mechanism for communicating uncertainty shall be employed.

Timeliness	Timeliness has two main elements: (1) data collection shall occur in a manner sufficient for adequate analyses before a management decision is needed, and (2) scientific information used shall be applicable to current situations. Timeliness also means that results from scientific studies and monitoring may be brought forward before the study is complete to address management needs[c]. In these instances, it is necessary that the uncertainties, limitations, and risks associated with preliminary results are clearly documented.
Peer review	The quality of the science used will be measured by the extent and quality of the review process. Independent external scientific review of the science is most important because it ensures scientific objectivity and validity. The following criteria represent a desirable peer review process[e]. Coordination of Peer Review. Independent peer review shall be coordinated by entities and/or individuals that (1) are not a member of the independent external review team/panel and (2) have had no direct involvement in the particular actions under review. Independent External Reviewers. A qualified independent external reviewer embodies the following qualities: (1) has no conflict of interest with the outcome of the decision being made, (2) can perform the review free of persuasion by others, (3) has demonstrable competence in the subject as evidenced by formal training or experience, (4) is willing to utilize his or her scientific expertise to reach objective conclusions that may be incongruent with his or her personal biases, and (5) is willing to identify the costs and benefits of ecological and social alternative decisions. When to Conduct Peer Review. Independent scientific peer review shall be applied formally to proposed projects and initial draft plans, in writing after official draft plans or policies are released to the public, and to final released plans. Formal peer review should also be applied to outcomes and products of projects as appropriate.

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a. McGarvey 2007
b. National Research Council 2004, Sullivan et al. 2006 c.
National Research Council 2004
d. Meffe et al. 1998
e. Adapted from Meffe et al. 1998

It is recognized that differences exist among the accepted standards of peer review for various fields of study and professional communities. When applying the criteria for best available science in Table 1A-1, the Council recognizes that the level of peer review for supporting materials and technical information (such as scientific studies, model results, and documents) included in the documentation for a proposed covered action is variable and relative to the scale, scope, and nature of the proposed covered action. The Council understands that varying levels of peer review may be commonly accepted in various fields of study and professional communities.

References

McGarvey, D. J. 2007. Merging precaution with sound science under the Endangered Species Act. Bioscience 57: 65-70.

Meffe, G. K., P. R. Boersma, D. D. Murphy, B. R. Noon, H. R. Pulliam, M. E. Soule, and D. M. Waller. 1998. Independent scientific review in natural resource management. Conservation Biology 12: 268-270.

National Research Council, Committee on Defining the Best Scientific Information Available for Fisheries Management. 2004. Improving the use of "Best Scientific Information Available" Standard in Fisheries Management. National Academy Press, Washington D.C. Available from http://www.nap.edu/catalog.php?record_id=11045#toc. Accessed June 2011.

Ryder, D. S., M. Tomlinson, B. Gawne, and G. E. Likens. 2010. Defining and using "best available science": a policy conundrum for the management of aquatic ecosystems. Marine and Freshwater Research 61: 821-828.

Sullivan, P. J., J. M. Acheson, P. L. Angermeier, T. Faast, J. Flemma, C. M. Jones, E. E. Knudsen, T. J. Minello, D. H. Secor, R. Wunderlich, and B. A. Zanetell. 2006. Defining and implementing best available science for fisheries and environmental science, policy, and management. American Fisheries Society, Bethesda, Maryland, and Estuarine Research Federation, Port Republic, Maryland. Available at http://www.fisheries.org/afs/docs/policy_science.pdf. Accessed June 2011.